*Reprinted from the Bulletin of The National Institute of Sciences of India, No. 1, 1952*

# ON CERTAIN PALAEOGEOGRAPHICAL FEATURES OF RAJASTHAN AS EVIDENCED BY THE DISTRIBUTION OF FISHES

*By*

**SUNDER LAL HORA**
*and*
**B. B. L. MATHUR**

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# ON CERTAIN PALAEOGEOGRAPHICAL FEATURES OF RAJASTHAN AS EVIDENCED BY THE DISTRIBUTION OF FISHES

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SUMMARY

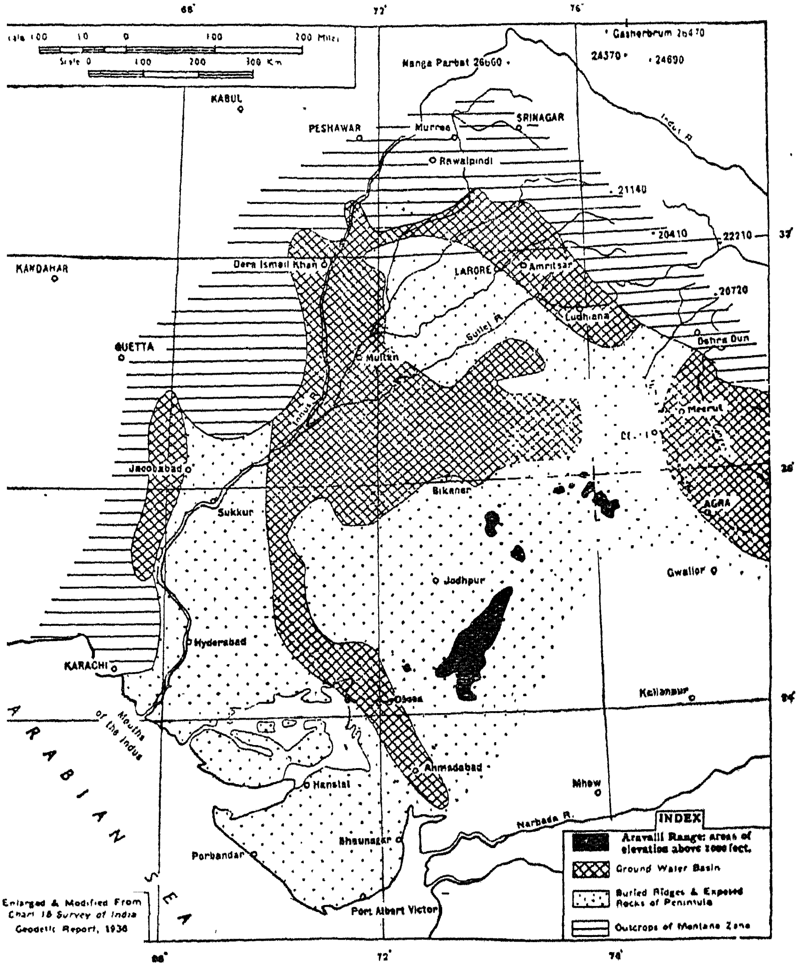
From the occurrence of a species of fish hitherto known from the Sind Hills in the Aravalli range, evidence is adduced to show that there was probably a hilly connection between the two areas though the intervening portion is now submerged below the sands. There are in the Aravallis, six species of fish which are typical of the fauna of Peninsular India. It would seem that during the late Himalayan movements, the northern and north-western parts of the once extensive Aravalli range sank with the result that there was down-warping of the range northwards. In this process, the aquatic fauna of the south may have had a chance to be transferred to the Aravalli range. The distribution of fishes thus points to great changes undergone by the Aravalli range both in height and extent during the late Himalayan movements. These changes had a profound effect on the physiography and climatology of Rajputana subsequently.

In the fish-fauna of Peninsular India, particularly of the Western Ghats, there is a marked Malayan element. To explain this anomaly in distribution, the senior author proposed the Satpura Hypothesis, which has now received considerable support from various branches of science. In order to find out any possible role of the Aravalli Ranges in the migration of the Himalayan fauna to Peninsular India, parties of the Zoological Survey of India made collections of the fauna in Rajasthan in 1941 and in 1948. The fishes in these collections have now been worked out by the junior author at the University of Delhi.

Of the 22 species found in these collections, 50% are widely distributed in the Indian Sub-Region, and are, therefore, of little value for zoogeographical studies. These are *Rasbora daniconius* (Ham.), *Barbus* (*Puntius*) *sarana* Ham., B. (*Puntius*) *sophore* Ham., *B.* (*Puntius*) *ticto* Ham., *Labeo boga* (Ham.), *L. calbasu* (Ham.), *Lepidocephalichthys guntea* (Ham.), *Nemachilus botia* (Ham.), *Glossogobius giuris* (Ham.), *Ophicephalus punctatus* Bloch and *Mastacembelus armatus* (Lacép.). There are four other species, *viz., Barilius bendelisis* Ham., *Esomus danricus* (Ham.), *Danio devario* (Ham.) and *Cirrhina reba* (Ham.), which are widely distributed in India and thus are of little significance for our present study. The remaining seven species are of great value, for their distribution indicates some remarkable palaeogeographical features of the country.

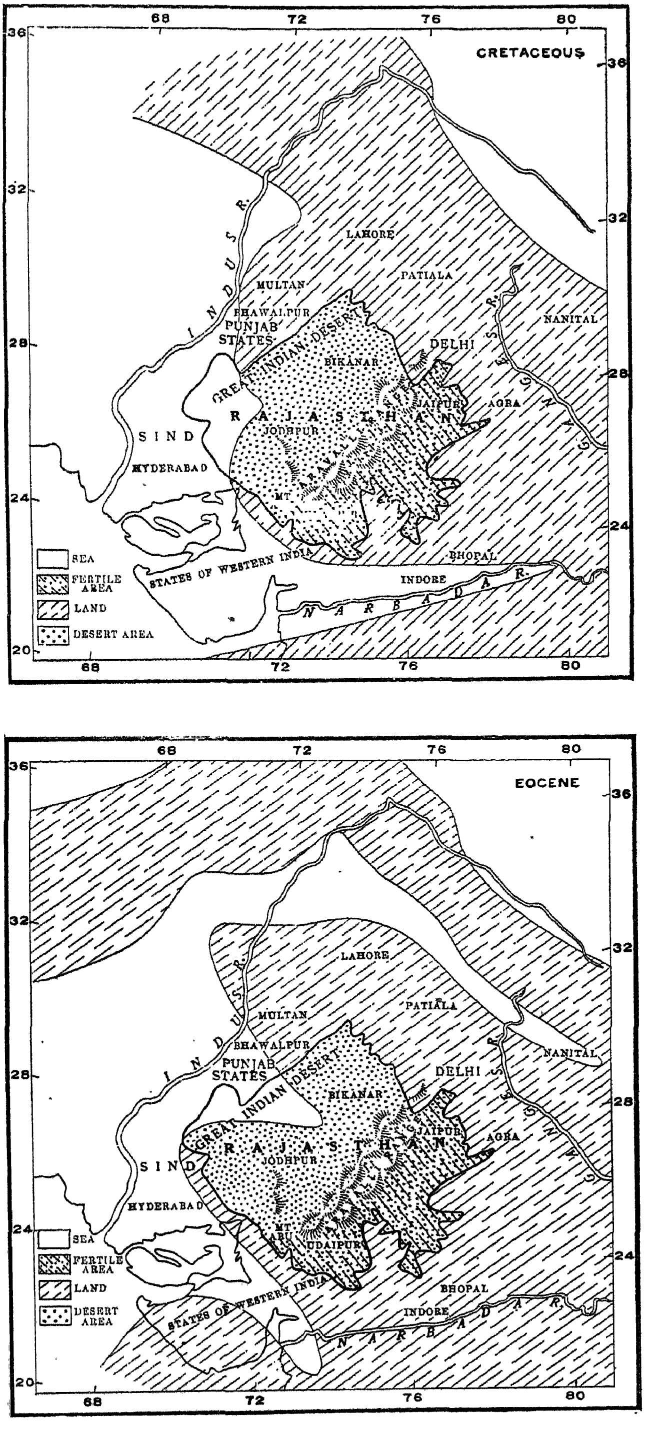
The occurrence in the Aravalli Range of *Labeo nigripinnis* Day, a species hitherto known only from the Sind Hills, raises points of great distributional significance, since the two hilly areas are at present separated by a long stretch of desert country. Glennie in Chart No. 15 of the Survey of India Geodetic Report for 1936 (Text-fig. 1) has, however, shown from the gravimetric and other geophysical evidence that concealed ridges exist under the desert sands which may have established a connection between the Kirthar Range of Sind and the Aravalli Ranges. Surface geology and strikes also indicate the probable occurrence of subsoil ridges. In fact, the present water-logging in the Western Punjab is stated to be due to the presence of such concealed ridges which obstruct the underground water of the Punjab alluvial basin from being drained

into the Ganga basin. The Sangala hills are probably the present-day stumps of one of these old ridges. It was probably along such land connections that *Labeo nigripinnis* of Sind may have migrated to the Aravalli Range.

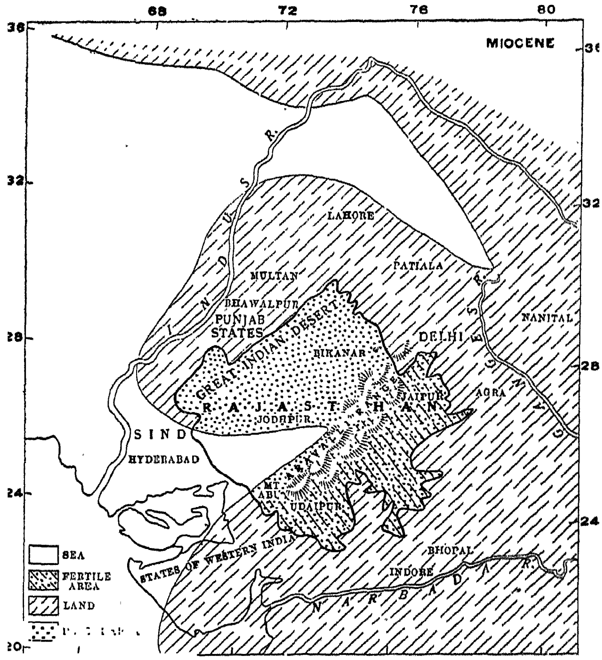


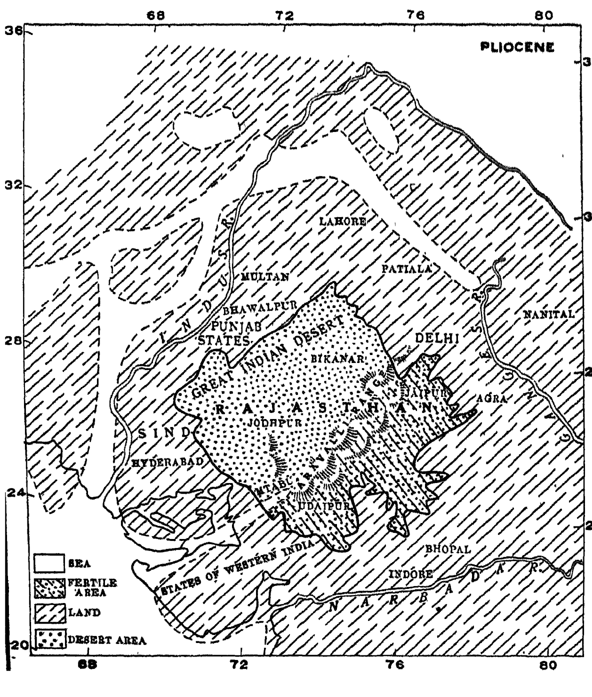

TEXT-FIG. 1. The Ground-Water Basins of North-West India (Modified after Auden 1950, pl. iv).

As regards the actual period of migration of *Labeo nigripinnis* from the Kirthar Range to the Aravalli Range, it may be noted that during the Cretaceous, Eocene (Text-fig. 2), and Miocene (Text-fig. 3) periods, the greater part of Sind was under the sea and that even during the Pliocene (Text-fig. 3 bottom) an arm of the sea intervened between the two regions. So the dispersal of the species probably took place during the Pleistocene. The individuals of the species in the Aravalli Range do not appear to be even racially differentiated from those occurring in Sind, which again points to the fact that the isolation of the stocks of the species is, comparatively speaking, a recent geological event. During the Pleistocene, there were five major Glacial Epochs when the sea level fell considerably and the land became relatively much higher. During Glacial periods, therefore, land




TEXT-FIG. 2.—Sea and Land Boundaries of North-West India during the Cretaceous ıd Eocene periods (Modified from MS maps supplied by the late Sir Cyril Fox in 1936).




TEXT-FIG. 3.—Sea and Land boundaries of North-West India during Miocene and Pliocene periods (Modified from MS maps supplied by the late Sir Cyril Fox in 1936).

connections of some elevation were established in areas which now seem to be at the sea level. From the non-existence of any evolutionary divergence between the two stocks, it seems most probable that *L. nigripinnis* migrated to the Aravalli Range during the last Glacial period which ended about 7,500 to 10,000 years ago.

The remaining six species, namely, *Chela clupeoides* Bloch, *Barbus* (*Tor*) *khudree* Sykes, *B.* (*Puntius*) *amphibius* (Cuv. & Val.), *Garra mullya* (Sykes) and *Nemachilus denisonii* Day, represent a group of species known only from Peninsular India and there can thus be no doubt that a part of the fish-fauna of the Aravalli Hills is derived from that source. According to Auden (1950, p. 18):

> "The visible portions of this range represent only the main orientation of its axis, but partially submerged extensions of the range show that it originally had a fan-shaped development, which includes a concealed ridge northwards from Narnaul, and then N.W.-S.E., past the visible inliers of Sangla and Karauli, to Shahpur at the foot of the Salt Range. The Aravalli range forms the pre-Cambrian backbone of the Peninsula which has resulted in the Pleistocene and Recent alluvial down-warps, formed in response to the late Himalayan movements, being confined to the three distinct basins of the Ganga, Amritsar-Ludhiana, and Multan, rather than forming one continuous zone".

The late Himalayan movements would seem to have resulted in the sinking of the northern and north-western extensions of the Aravallis with the result that through the process of downwarping the typical forms of the Satpuras and of the Sind Hills got dispersed to the Aravalli range. The common carp-minows and some air-breathing species of the Indo-Gangetic basin also reached the Aravallis during this process. Though the fauna of the Aravalli range is at present isolated from that of Sind and the Peninsula, as pointed out already, no racial differences have been observed among them which shows that isolation is, geologically speaking, of a comparatively recent date. The absence of any endemic species in the Aravalli Range also points to the same conclusion. Thus the evidence provided by the distribution, non-raciation and non-endemicity of the Aravalli fishes indicates that this range has undergone great changes, both in height and extent, during the later Himalayan movements. Though at present, the Aravalli range is not an effective barrier to the spread of the sand of the great Thar Desert, which now stretches up to its western flank, at one time it must have protected parts of the present Rajputana Desert from arid zone influences. Recent changes in the height and extent of the Aravallis, no doubt, had a profound effect on the physiography and climatology of Rajputana.

## REFERENCE

Auden, J. B., 1950. Introductory Report on the Ground-water Resources of Western Rajasthan. *Bull. Geol. Surv. India* (B.), 1, pp. 59.

## EXPLANATION OF PLATE XVII.

SHAPED RAFTS FROM INDIA AND SEISTAN.

FIG. 1.—Fisherman's *tutin* among the reed-beds (Scirpe of the Hamun-i-Helmand.

,, 2.—Men and boys making a *tutin* on the shore o same lake.

,, 3.—Fisherman's *bindi* on swamp near Roorkee,

RECORDS

of the

INDIAN MUSEUM

Vol. XXXIII, Part I, pp. 67—69

# Classification of the Homalopterid Fishes.

By

S. L. HORA

CALCUTTA:

MARCH, 1931

# CLASSIFICATION OF THE HOMALOPTERID FISHES.

*By* SUNDER LAL HORA, *D.Sc.* (Punj. et Edin.), *F.R.S.E.*, *F.L.S.*, *F.Z.S.*, *F.A.S.B.*, *Zoological Survey of India, Calcutta.*

The taxonomy of the Homalopterid fishes has been involved in a great confusion and this fact has greatly impeded the progress of my work on the bionomics and evolution of the Homalopteridae. During my visit to Europe in 1927-29 I availed myself of the opportunity of examining the collections of these fishes in the British Museum, as well as in the zoological museums at Paris, Leiden, Amsterdam, Berlin and Genova. With the knowledge thus gained I am preparing an account of the generic classification, bionomics and evolution of the Homalopterid fishes, but as this work is likely to take some time yet and as the study is fairly advanced I have thought it advisable to give in this short note my views on the classification of the family.[1]

The Homalopterid fishes constitute a remarkable family of torrent-inhabiting loaches which are characterised by a subterminal and inferior mouth, a flattish lower surface and horizontal paired fins with the anterior rays "simple". As I have indicated elsewhere,[2] the so-called simple rays are of two kinds. In *Balitora*, for example, the simple rays are apparently produced by the coalescence of the branches of an ordinary ray, whereas in *Gastromyzon* there is only one true simple ray, the neighbouring rays, although appearing simple superficially, being in reality forked. In this last case the primary branching is retained and each of these branches is then modified into a simple ray. On the morphological structure of the "simple" rays the members of the family Homalopteridae can be grouped into two subfamilies—Homalopterinae and Gastromyzoninae.[3] The former is characterised by the presence of *two or more* undivided rays in the paired fins, whereas the latter possesses only *one* undivided ray in the paired fins. The genera *Homaloptera*, *Balitora*, *Hemimyzon*, *Sinogastromyzon*, *Sinohomaloptera*, *Chopraia* and *Lepturichthys* are thus referrable to the Homalopterinae and the genera *Parhomaloptera*, *Pseudogastromyzon*, *Gastromyzon*, *Crossostoma* and *Formosania* to the Gastromyzoninae. The remaining genera such as *Glaniopsis*, *Homalosoma* and *Octonema* are more closely related to the Cobitidae than to the Homalopteridae.

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[1] After this article had gone to press I received a copy of Mr. P. W. Fang's very interesting paper entitled "New and Inadequately Known Homalopterin Loaches of China" (*Contributions Biol. Lab. Sci. Soc. China, Zool. Ser.* VI, No. 4, pp. 25-43, 1930), in which he gives a rearrangement and revision of the generic characters of *Gastromyzon*, *Sinogastromyzon* and their related genera. It is not possible to discuss his system of classification in this note, but I hope to do so in the near future when publishing a detailed account of the classification, bionomics and evolution of the Homalopterid fishes.

[2] Hora, *Phil. Trans. Roy. Soc. London* (B) CCXVIII, p. 267 (1930).

[3] I am retaining the subfamily designations proposed by Fowler (*Proc. Acad. Nat. Sci. Philad.* (2) LVII, pp. 475, 477; 1905), though my characterisation of the two subfamilies is entirely different from that given by Fowler.

Among the Homalopterinae, *Homaloptera*, *Balitora*, *Hemimyzon* and *Sinogastromyzon* form a regular graded series, while the 8-barbelled *Sinohomaloptera*, the many-barbelled *Lepturichthys* and the large-eyed *Chopraia* represent side branches of the main stem of evolution. Similarly among the Gastromyzoninae, *Parhomaloptera*, *Pseudogastromyzon* and *Gastromyzon* constitute a regular series, whereas the many-barbelled *Crossostoma* and *Formosania* seem to have diverged from the main line. A close study of the two subfamilies shows that evolution has proceeded among them along parallel lines and the most specialized forms of the two subfamilies show remarkable convergence of characters. It is interesting to note that both in *Sinogastromyzon* and in *Gastromyzon* the ventral fins are united posteriorly to form a disc for the purposes of adhesion.

For convenience of reference I give below a list of the genera of the Homalopteridae with references to their original descriptions and the names of the type-species with such other information as I consider it is desirable to publish at this stage of my work.

## Subfamily **Homalopterinae.**

1. *Homaloptera* van Hasselt, *Algem. Konst-en Letterbode* II, p. 130 (1823).
   *Type-species* :—*Homaloptera wassinki* Bleeker (=*H. fasciata* van Hasselt).
   *Synonyms* :—*Helgia* Vinciguerra. *Homalopteroides* Fowler and *Bhavania* Hora.
2. *Balitora* Gray, *Illstr. Ind. Zoology* I, pl. lxxxviii, fig. 1 (1832).
   *Type-species* :—*Balitora brucei* Gray.
3. *Hemimyzon* Regan, *Ann. Mag. Nat. Hist.* (8) VIII, p. 32 (1911).
   *Type-species* :—*Hemimyzon formosanum* (Boulenger).
   *Homaloptera abbreviata* Günther (Pratt's *Snows of Tibet*, p. 248, pl. iii, fig. B, 1892) and *Psilorhynchus sinenses* Sauvage et Dabry (*Ann. Sci. Nat. Paris* (6) I, art. 5, p. 14, 1874) belong to the genus *Hemimyzon*.
4. *Sinogastromyzon* Fang, *Sinensia* I, p. 35 (1930).
   *Type-species* :—*Sinogastromyzon wui* Fang.
5. *Sinohomaloptera* Fang, *Sinensia* I, p. 26 (1930).
   *Type-species* :—*Sinohomaloptera kwangsiensis* Fang.
6. *Chopraia* Prashad & Mukerji, *Rec. Ind. Mus.* XXXI, p. 188 (1929).
   *Type-species* :—*Chopraia rupicola* Prashad & Mukerji.
7. *Lepturichthys* Regan, *Ann. Mag. Nat. Hist.* (8) VIII, p. 31 (1911).
   *Type-species* :—*Lepturichthys fimbriata* (Günther).

## Subfamily **Gastromyzoninae.**

8. *Parhomaloptera* Vaillant, *Notes Leyden Mus.* XXIV, p. 129 (1902).
   *Type-species* :—*Parhomaloptera microstoma* (Boulenger).
9. *Pseudogastromyzon* Nichols, *Amer. Mus. Novitates*, No. 167, p. 1 (1925).

*Type-species* :—*Pseudogastromyzon fasciatus* Sauvage [1] (=*P. zebroidus* Nichols).

10. *Gastromyzon* Günther, *Ann. Mag. Nat. Hist.* (4) XIV, p. 454 (1874).

    *Type-species* :—*Gastromyzon borneensis* Günther.

    *Synonyms* :—*Lepidoglanis* Vaillant and *Neogastromyzon* Popta.

11. *Crossostoma* Sauvage, *Bull. Soc. Philom. Paris* (7) II, p. 88 (1878).

    *Type-species* :—*Crossostoma davidi* Sauvage.

12. *Formosania* Oshima, *Ann. Carnegie Mus.* XII, p. 194 (1919).

    *Type-species* :—*Formosania formosanum* (Steindachner) [2] (=*F. gilberti* Oshima).

[1] Sauvage, *Bull. Soc. Philom. Paris* (7) II, p. 88 (1878).
[2] Steindachner, *Ann. Akad. Wiss. Wien* XLV, p. 82 (1908).

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*To*..........................................

*With the Author's compliments.*

# A FRESHWATER FISH FROM THE OIL-MEASURES OF THE DAWNA HILLS

BY

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(With Plate 14)

[From the Records, Geological Survey of India, Vol. LVI,
Part 3, 1925.]

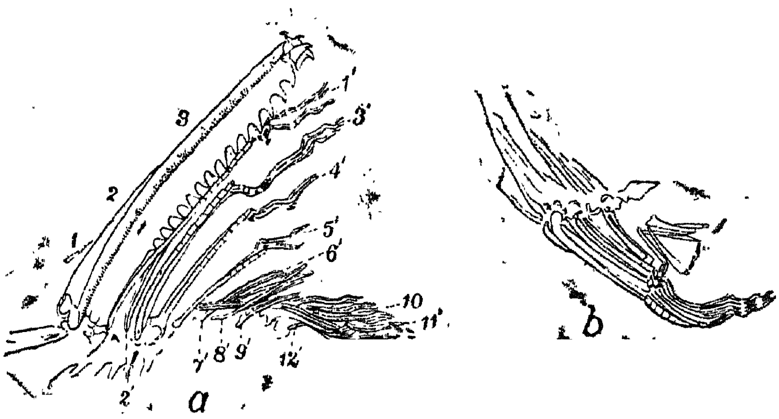
# A Freshwater Fish from the Oil-measures of the Dawna Hills. By the late N. Annandale, C.I.E., D Sc., F.R.S., F.A.S.B., *Director* & Sundar Lal Hora, D.Sc., *Assistant Superintendent, Zoological Survey of India.* (With Plate 14.)

The fish described in this note was collected by Professor J. W. Gregory, F.R.S., at Mepale in the Dawna Hills, Tenasserim. Its remains are preserved in stiff clay evidently of lacustrine origin and associated with the limestone in which the shells [1] from the same locality which one of us has recently described were obtained. The type-specimen will be returned to Glasgow University.

The species evidently belongs to the family Cyprinidæ and we believe to the subfamily Cyprininæ, but its characters are so distinct that a new genus must be set up for it. We propose for it the name :—

DAUNICHTHYS, gen. nov.

The head is large and about as deep as the body. It was apparently flattened above with the eyes in its upper half. The jaws are not suctorial. The body is short and moderately deep.




Text-fig. 1.—Dorsal and anal fins.

(*a*) Dorsal fin ;
(*b*) Anal fin.

1, 2, 3 bony spines of the dorsal ; 1'-12' branched and flexible rays of the dorsal.

[1] Annandale, *Rec. Geol. Surv. Ind.*, LV, pp. 97-104, (1923).

There are at least 31 vertebrae, of which 13 appear to be caudal and the caudal and trunk regions are about equal in length. The lateral line runs along the tail below the vertebral column.

The dorsal fin is situated near the middle of the body and is of moderate length. There are at least 15 rays, of which about 12 are branched. The last bony ray is stout and strongly serrated in its upper two-thirds. The caudal fin is long and deeply notched, with the two halves pointed and equal. The ventral lies below the dorsal and has more than six rays, none of which is strongly developed. The anal, which is situated behind the dorsal, is of moderate length and contains two unbranched and 9 branched rays. There is no trace of scales in the specimen.

DAUNICHTHYS GREGORIANUS, sp. nov.

D. 3/12 ; A. 2/9 ; P. 7+; V. 6+; C. 30.

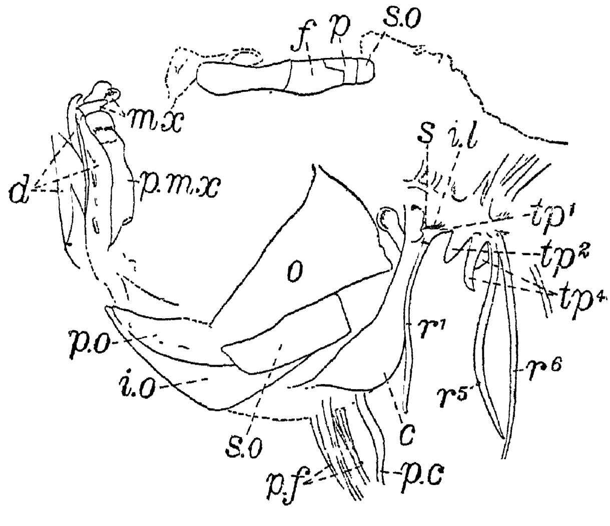
The length of the head is contained 3 times in the total length without the caudal fin. It is as deep as the body. The greatest depth of the body is contained a little over 3 times in the total length without the caudal. The dorsal fin was probably as high as the depth of the body below it. Its first bony ray is short, the second of moderate length and the third much longer and deeply grooved throughout its length. The branched rays of this fin and certain rays of other fins are longitudinally grooved. The pectorals and the ventrals are widely separated and cannot have overlapped. The commencement of the anal is nearer to the ventrals than to the base of the caudal.

The total length of our example is 56 mm., that of the head 14·2 mm., the greatest depth of the body 14 mm., and the length of the caudal fin 13 mm.

Having thus described the genus and the species we will now proceed to examine the specimen in greater detail.

*Skull and associated structures* :—In the region of the head the jaw-bones, the opercular bones, the secondary pectoral arch and the bones of the brain-case can be distinguished after careful examination, but the other bones have been completely broken up. It seems, however, quite probable that there was a complete circum-orbital ring for traces of it can still be made out. Of the jaw-bones, the lower jaw is broken in the middle longitudinally, while the dentary of the unexposed side, which is also visible, is further broken

into two pieces. The maxillaries are represented by nodule-like bones at the top of the premaxillary, which is closely approximated to the dentary. From the direction of the jaws, which are directed




TEXT-FIG. 2.—Bones of the jaws, operculum etc. and the anterior modified vertebrae. $d$ = dentary; $mx$ = maxilla; $p.\ mx$ = premaxilla; $p.\ o.$ = preoperculum; $i.\ o.$ = interoperculum; $s.\ o$ = suboperculum; $o.$ = operculum; $p.\ f$ = pectoral fin; $p.\ c.$ = post clavicular process; $c.$ = cleithra; $tp^1$ = transverse process of first vertebra; $tp^2$ = transverse process of second vertebra; $tp^4$ = transverse process of fourth vertebra; $r^1$ = rib of first vertebra; $r^5$ = rib of fifth vertebra; $r^6$ = rib of sixth vertebra; $s$ = scaphium; $i.\ l.$ = interossicular ligament; $f$ = frontal; $p$ = parietal; $s.\ o$ = supraoccipital.

almost vertically upwards in the specimen, it is evident that the mouth-opening must have been directed obliquely upwards as in the living *Catla.* The four opercular bones are quite clear and are well developed. It seems to be quite clear from the position of these bones that they have been detached from the jaw-bones *post mortem* and have been pushed backwards and downwards by external pressure. The secondary pectoral arch is complete and well developed. It is not emarginate anteriorly, but exhibits a somewhat primitive form of the cleithra.[1] The rib-shaped post-clavicular process of the secondary arch is also well marked. Lying alongside the posterior border of the cleithra is a rib-shaped structure, which in all probability represents a rib of the first vertebra, for we know of no other similar structure in this position in the living fishes.

[1] Regan, *Ann. Mag. Nat. Hist.*, (8) VIII, p. 28 (1911).

The brain-case is cracked in several places, but the supraoccipital, the parietal and the frontal can be made out.

*Vertebral Column* :—In considering the vertebral column of a Cyprinoid fish the chief interest lies in the modification of the anterior vertebrae.[1] This fossil specimen is unique, so far as we are aware, in having a rib of the first vertebra distinct and well developed. The existence of a separate distinct first rib is a very primitive character, but even in living forms the first vertebra possesses a well developed transverse process and in *Catla catla* this is usually an elongated rib-like structure, reaching to about the middle of the transverse process of the second vertebra. The scaphium and a portion of the inter-ossicular ligament of the weberian apparatus are also seen in our specimen slightly above the origin of the rib of the first vertebra. All the trunk vertebrae are covered with skin and muscles and it is difficult to make out their exact structure. Those of the tail region are very clear and are exactly similar to the tail-vertebrae of such fishes as *Labeo rohita*, *Barbus tor* and *Catla catla*. The skeleton of the caudal fin is also similar to that of these species.

*Integument*.—We can find no trace of scales either detached or *in situ*, but the lateral line is quite clear in the anterior half of the body and can be traced along the caudal peduncle. It lies below the vertebral column and has a slight downward curvature anteriorly, while on the tail it seems to have been nearly straight and to have run parallel to and just below the vertebrae.

*Affinities of Daunichthys*:—From what has been said above it is abundantly clear that the new genus belongs to the family Cyprinidae and probably to the subfamily Cyprininae. The following combination of characters, however, distinguishes our new genus from all living and fossil genera of the family.

The anal fin is provided with 9 branched rays and does not extend to below the dorsal; the lateral line runs below the vertebral column and in the tail it was probably situated in the lower half of the body; the dorsal fin possesses 12 branched rays and 3 spines, the last spine is deeply grooved longitudinally on the right side and is strongly denticulated posteriorly and the body is entirely scaleless.

In its general facies *Daunichthys gregorianus* resembles certain species of the genus *Barbus* (*s. l.*) and in its up-turned mouth those

[1] HORA, *Journ. As. Soc. Bengal*, (*n. s.*) XVIII, pp. 1-4 (1922).

of *Catla.* Neither *Barbus* nor *Catla,* however, possesses more than six branched rays in the anal fin and both are provided with well developed scales.

A deeply grooved dorsal spine is characteristic of certain living scaleless North American genera of Cyprinoid fishes such as *Meda* and *Plagopterus.* In these this spine is, however, composed of two rays, "the posterior received into a longitudinal groove of the anterior."[1] In the only scaleless Cyprinid fish of the Oriental Region (*Sawbwa resplendens* [2] from the Southern Shan States) the dorsal spine is not grooved and is normal in every respect.

In the following table are given some of the chief characters in which the fossil Cyprinid genera of the Oriental region are distinguished from one another. Of the other fossil genera of the family,[3] some are known from America and others from Europe. Most of these are either described from the remains of the pharyngeal bones and teeth or are characterized by the possession of a long dorsal fin without an osseus spine. In none of these in which the dorsal fins are preserved, are the rays grooved like those of *Daunichthys.*

The Geological Survey of India has recently received from a boring in the Tenasserim coalfield at Kawamapyin, Mergui, certain samples of clay very similar to that in which *Daunichthys* is preserved. They were obtained at a depth of 208 feet. They contain fish spines, which at first sight are very similar to the last bony ray of *Daunichthys,* but closer examination shows that they differ in not being grooved as well as minor characters. It is impossible to assign them to any genus or family with certainty, but they are probably from a dorsal fin of a Cyprinid.

[1] Jordan and Evermann, *Bull. U. S. Nat. Mus.*, XLVII, Part I, p. 328 (1896).

[2] Annandale, *Rec. Ind. Mus.*, XIV. p. 48 (1918).

[3] For an up-to-date list of fossil genera of the family Cyprinidae see names in italics in Jordan's *Classification of Fishes,* pp. 139-144 (Stanford University, California : 1923).

| *Thynnichthys.** | *Amblypharyngodon.** | *Barbus* (s. l.).* | *Hexasephus.*† | *Brachyspondylus.*‡ | *Daunichthys*, gen. nov. |
|---|---|---|---|---|---|
| Dorsal without osseous ray, with 10-12 branched rays. | Dorsal without osseous ray, with 7-8 branched rays. | Dorsal with or without osseous ray, the last osseous ray may or may not be strongly denticulated; with 7-9 branched rays. | .... | One osseous ray and 8 branched rays in dorsal. | Dorsal with 3 osseous rays, the last being grooved and strongly denticulated posteriorly; with 12 branched rays. |
| Anal with 5 branched rays. | Anal with 5, 6 branched rays | Anal with 5 branched rays. | .... | Anal with 10 branched rays. | Anal with about 9 branched rays |
| Ventrals commencing below dorsal. | Ventrals commencing in advance of dorsal. | Ventrals below root of dorsal. | .... | .... | Ventrals slightly behind commencement of dorsal. |
| Anal entirely behind dorsal. | Dorsal extending nearly to commencement of anal. | Anal behind dorsal. | .... | Anal behind dorsal. | Anal behind dorsal. |
| Scales present. | Scales present. | Scales present. | .... | (No indication of scales in the figure.) | No scales. |
| Pharyngeal teeth with a flat, oblong crown; 5 or 4, 4 or 3, 3 or 2-2 or 3, 3 or 4, 4 or 5. | Pharyngeal teeth molariform with flats or concave crown; 3, 2, 1-1, 2, 3. | Pharyngeal teeth uncinate or spoon-shaped; 5, 3, 2-2, 3, 5. | Pharyngeal bone with 3 large mammaliform teeth arranged in a single series. | | |

* We have followed Day's *Fishes of India* in our definitions of these genera, which still persist, but *Barbus* is broken up by some (not by all) recent ichthyologists into a number of smaller genera (see Weber and Beaufort's *Fishes of the Indo-Australian Archipelago* III, pp. 89-238 (1916).

† Marck, *Palaeontographica*, XXII, p. 411, pl. xxiii, fig. 2; pl. xxiv, fig. 2 (1876).

‡ Günther, *Geol. Magazine* (n. s.) III, p. 439, pl. xvi, figs. 2, 3a, 3b, 3c (1876).

Z. S. I. Photo.

DAUNICHTHYS GREGORIANUS, *SP. NOV.* × 3

G. S. I. Calcutta.

*To*.............................................

*With the Author's compliments.*

# A NOTE ON THE MALERI BEDS OF HYDERABAD STATE (DECCAN) AND THE TIKI BEDS OF SOUTH REWA.

BY

**N. K. N. AIYENGAR, M.A.,**

FIELD COLLECTOR, GEOLOGICAL SURVEY OF INDIA.

**(With Plate 34.)**

# A NOTE ON THE MALERI BEDS OF HYDERABAD STATE (DECCAN) AND THE TIKI BEDS OF SOUTH REWA. BY N. K. N. AIYENGAR, M. A., *Field Collector, Geological Survey of India.* (With Plate 34.)

Among the Gondwana rocks of India, the three chief places where Triassic reptilian fossils occur are, (1) near Deoli in the Panchet rocks, Raniganj coalfield, (2) around Maleri in the Pranhita-Godavery valley, Hyderabad State, and (3) at Tiki in south Rewa.

The writer was deputed to collect reptilian fossils near Tiki in 1929-30 and 1935, and Maleri in 1935. As these localities were not easily accessible, few geologists have visited them in recent times.

## (1) Deoli.

The presence of Triassic reptilian fossils has already been recorded in the Panchet beds of the Raniganj coalfield. They occur chiefly

'Just[1] North of the village of Deoli, near Bakúlia, and about quarter of a mile East of the mouth of the Besram stream, a considerable expanse of rocks is exposed in the bed of the Damúda, South of the channel occupied by the water in the dry season, and here a bone bed was found, containing detached, and, frequently, rolled bones, vertebræ, and fragments of jaws with teeth; they are not very abundant, but a considerable number were procured. Some were also found in another spot in the Damuda, a little East of the village of Dikha and fragments of bone were occasionally met with in other localities.'

The fossils from these beds have been described by Thomas Huxley[2] and W. T. Blanford[3]. The latest account of these Panchet beds is to be found in Mr. E. R. Gee's memoir on the Raniganj coalfield.[4]

## (2) Maleri.

Maleri (Marweli of the map, sheet 56 M/12; 19° 11′ : 79° 36′) is a village ten miles E. N. E. of Rechni Road railway station on

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 1, p. 129, (1861).
[2] *Quart. Journ. Geol. Soc.*, XVII, Pt. 1, p. 362, (1861). *Pal. Ind.*, Ser. IV, Vol. I, Pt. I, (1865).
[3] *Pal. Ind.*, Ser. IV, Vol. I, Pt. I, p. 25, (1865).
[4] *Mem. Geol. Surv. Ind.*, LXI, pp. 54-59, (1932).

the Kazipet-Balharshah section of H. E. H. the Nizam's State Railway in the Asafabad district of Hyderabad.

Though the earliest geological work in this area began as long ago as 1833, definite geological and palæontological work of interest was first commenced by the Rev. S. Hislop[1] in 1856. Later investigators were T. Oldham[2], W. T. Blanford[3], T. W. H. Hughes[4], R. Lydekker[5] and W. King[6].

The writer's work was chiefly confined to the central part of the Maleri formation around Maleri itself, though he traversed some parts in the southern area as well. The present description refers mainly to the country in the neighbourhood of Maleri.

**Lithology.**

The country near Maleri is slightly undulating, with a few shallow streams. The land is covered either with black cotton soil or Maleri red clays. In some places chipped rocks (Palæolithic flints) are found. As in the case of the Tiki formation, which will be described later, in the Maleri beds sandstones are subordinate to clays. A good and complete section of the rocks of the Maleri formation is not seen near Maleri itself, but after examination of some of the exposures south-west of Maleri and at the water gate of Rampur village (Pl. 34, fig. 1), the writer thinks that the following generalised section will give an idea of the probable stratigraphy of the formation near Maleri :—

| | Feet. |
|---|---|
| Black cotton soil . . . . . . . . . . . | 2—4 |
| Sandstone boulder bed . . . . . . . . . | 2 |
| White or light grey, felspathic, occasionally calcareous, sandstone. (In some places this sandstone is considerably decomposed and mixed with much *kankar*) . . . . . | 4—7 |
| Nodular, cherty looking, calcareous rock (seen south-west of Maleri) . . . . . . . . . . . . | 5 |
| Fine grained thinly laminated, grey calcareous sandstone, showing false bedding . . . . . . . . . | 5 |
| Coarse rubbly calcareous sandstone. (This bed has yielded reptilian fossils in certain places) . . . . . . | 2—3 |
| Red clay,—thickness not known. | |

[1] *Quart. Journ. Geol. Soc., London,* XVII, p. 348, 1861, XX, p. 280, (1864). *Journ. Bombay Br. R. A. S.,* Vol. VI, p. 202, (1861).

[2] *Mem. Geol. Surv. Ind.,* I, pp. 295-309, (1859).

[3] *Mem. Geol. Surv. Ind.,* IX, pp. 295-330, (1872), Pal. Ind. Ser., iv, Vol. 1, Pt. 2, pp. 17-23, (1878).

[4] *Rec. Geol. Surv. Ind.,* IX, p. 86, (1876).

[5] *Pal. Ind. Ser.,* IV, Vol. I, Pt. 5, (1885).

[6] *Mem. Geol. Surv. Ind.,* XVIII, Pt. 3, pp. 118-123, (1881).

Owing to their softness, the red clays do not show any bedding, but the rubbly sandstone bed immediately overlying them shows a dip of 10°-12° in a north-east or N. N. E. direction.

Though the Maleri formation extends from Sandgaom (19° 35′ : 79° 42′) to Semnapali (18° 42′ : 79° 54′), a distance of about 60 miles, reptilian fossils have been found only in the central part of this area, that is, between Maleri and Nannial (19° 4′ : 79° 38′), and in the Angrezapalli (18° 48′ : 79° 47′) outlier. The reason for this appears to be that the beds containing fossils have been well exposed in these places owing to the gentle dip, which has allowed rapid weathering of the rocks, and has also prevented the fossils so exposed from being washed away by rains. Such is the country bounded by the villages, Teklapalli (19° 8′ : 79° 35′), Nannial (19° 4′ : 79° 38′), Kanepalli (19° 9′ : 79° 40′), Venkatapur (19° 11′ : 79° 38′), Bhimni (19° 12′ : 79° 38′) and Achlapur (19° 10′ : 79° 32′).

Fossil collection.

Owing to the flatness of the country and constant cultivation, fossils are sparsely distributed. One of the best methods adopted by previous workers like Hislop and Hughes for collecting fossils in this area which met with much success, was by "beating" (Pl. 34, fig. 2). In making further collections, the same method was followed by the writer, whose provisional identifications of the fossil collections from Maleri are as follows :—

(1) One mile north-east of Maleri in the stream exposures.

*Hyperodapedon huxleyi*, Lyd.—Maxilla, dentary bones and scutes.

*Parasuchus* sp.—Teeth, vertebræ and imperfect limb bones.

*Belodon* sp.—Limb bones.

*Unio* sp.—

(2) Half a mile north of Maleri in the black soil.

*Hyperodapedon* sp.—Vertebræ and bones.

Labyrinthodont.—Dentary bones.

*Unio* sp.—

(3) One mile north-west of Maleri in the red clay.

*Hyperodapedon* sp.—Maxillæ.

*Unio* sp.—

(4) One mile south-west of Maleri.

Large limb bones, vertebræ, scutes, maxillary and dentary fragments, probably belonging to *Belodon*. All these specimens

were collected at one spot, and they may belong to the same individual.

(5) About five furlongs north of the last mentioned locality, were found two large ? Dinosaurian vertebræ and two or three species of the fish *Ceratodus*. In addition to these fossils, coprolites are abundant about half a mile W. S. W. of Maleri. They are generally greenish yellow in colour varying in size from that of a walnut to a cocoanut. In shape some are flat and cake-like, some cylindrical, spiral, reniform or botryoidal. In cross section they present a central core surrounded by layers of iron-impregnated material. The nature of the material of these coprolites collected has not yet been examined.

(6) One mile E. S. E. of Achlapur.

*Hyperodapedon* sp.—Bones, imperfect maxillæ.

*Unio* sp.—

(7) Half a mile north of Rechni village.

Remains of *Hyperodapedon* sp. and *Unio* sp.; the latter are much smaller in size than those found at Maleri.

## (3) Tiki.

Tiki (81° 22′ : 23° 56′) sheet 64 E/5, is a small village about seven miles south of Beohari, and about fifty miles north-east of the Umaria coalfield in south Rewa. The best route to this locality is *viâ* Sutna and Rewa.

**Previous observers.**

Reptilian fossils were first noticed near Tiki by T. W. H. Hughes about the year 1879, during the course of his survey of the south Rewa Gondwana basin[1]. The collection made by him in this area has been described by Lydekker[2]. Dr. G. de P. Cotter,[3] who visited this place during the year 1916 to investigate the relationship of the Tiki beds with the Parsora formation, also collected some reptilian remains near Tiki.

**Topography.**

Like most Gondwana areas, the country around Tiki is slightly undulating. The softer red clays and sandstones have been much denuded. Wherever harder rocks like the ferruginous sandstones of the upper division

[1] *Rec. Geol. Surv. Ind.*, XIV, Pt. 1, p. 136, (1881).
[2] *Pal. Ind.*, Ser. IV, Vol. I, Pt. 5, (1885).
[3] *Rec. Geol. Surv. Ind.*, XLVIII, Pt. 1, p. 27, (1917).

protect the clays below, they give rise to flat-topped hills, like the Hartala and Beohari hills.

Lithology.

As already mentioned the rocks can be divided into two distinct lithological divisions. The upper division is chiefly composed of hard ferruginous sandstones with rounded pebbles at the top. These beds overlie fine-grained grey hard sandstones with red laminations, and some purple shales. Some good varieties of such rocks are quarried near Beohari for building purposes. So far no fossils, either plant or animal, which would help in determining their age, have been found in these rocks. They may represent the upper division of the Tiki beds or may be younger than the latter. The lower division, known as the Tiki stage, in which reptilian fossils, fossil wood, and fresh-water shells like *Unio* occur, is made up mostly of red and green clays with subordinate sandstones. These sandstones are often calcareous. Fine green laminations and green clay galls are very characteristic of these sandstones, and in some places the calcareous matter segregates on the surface of the sandstones near Tiki and forms a thick vermicular encrustation on them. False bedding is very common, and calcified or carbonised fossil wood is sometimes found. The red clays, being softer and more easily denuded, form the lower ground. They are full of yellow *kankar*. The red clays make their first appearance in the Son River section a mile up the stream from Giar. The following section, which is seen on the right bank of the Son at Giar (23° 30′ : 81° 19′), may be taken as a type one for the Tiki beds :—

| | Feet. |
|---|---|
| Siliceous sandstones, grey and brown in colour with decomposed felspars and clay galls . . . . . . . | 15 |
| Fine-grained grey sandstones with interrupted green laminations, false-bedded, and containing partly carbonised and calcified fossil wood . . . . . . . | 5 |
| Weathered calcareous rubbly grey sandstone . . . | 2 |
| Fine-grained sandstone . . . . . . . . . | 2 |
| Bright red clays,—thickness not known. | |

This section has also been noticed by Hughes.

Though the red clays are found to cover a considerable area, fossils have been found only in those south of Tiki. In this locality reptilian and molluscan fossils are found on the much denuded clays. Most of the fossils are covered with calcareous matter and are much worn. Not a single fossil was seen *in situ*. It is not

definitely known from which beds these fossils are derived, but some fragments of fossils were enclosed in a rubbly calcareous matrix which occurs above the red clays. The writer, however, noticed in the Godavery area that fossils were present in such calcareous sandstones. The following fossils were found in the collection made near Tiki :—

*Hyperodapedon huxleyi*, Lyd.—Fragmentary palato-maxillæ, dentary bones, vertebræ, etc.

*?Dinosaurian.*—Tooth.

*Belodon* sp.—Fragmentary maxilla, vertebra and teeth.

*Parasuchus* sp.—Limb bones, scutes and teeth.

An interesting frontal part of the internal cast of a saurian skull was also collected.

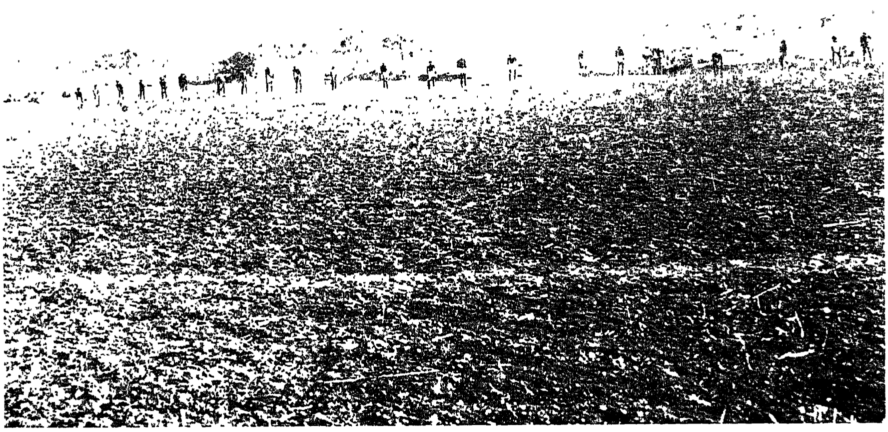
*Unio* sp.—

(Fish teeth, which are fairly common in the Maleri area, have not been found at Tiki.)

## EXPLANATION OF PLATE.

PLATE 34, FIG. 1.—Exposure of Maleri beds at Rampur near Maleri.
FIG. 2.—Searching for reptilian fossils at Maleri, Hyderabad State.

FIG. 1. EXPOSURE OF MALERI BEDS AT RAMPUR NEAR MALERI.



*N. K. N. Aiyengar, Photos.* *G. S. I., Calcutta.*

FIG. 2. SEARCHING FOR REPTILIAN FOSSILS AT MALERI.

TIN OF THE BIOGEOGRAPHICAL SOCIETY OF JAPAN

issued by the

BIOGEOGRAPHICAL SOCIETY
OF JAPAN

7 日本生物地理學會會報 January 1936

# DIES ON THE GEOGRAPHICAL DISTRIBUTION OF FRESHWATER FISHES IN CHÔSEN

By Tamezo Mori

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## I Physical Features and Climate

physical features and climate of Chosen which have direct with the distribution of freshwater fishes in Chosen, have ated of in my paper "On the Geographical Distribution an Salmonoid Fishes. Bull. Biogeogr. Soc. Japan, VI, No. -9, pls. 1–3 (1935)". The reader is referred to that paper ng the above subject.

## Historical Sketch concerning the Investigations of Freshwater Fishes in Chosen

investigations concerning freshwater fishes in Chosen have newhat belated compared with those of Japan Proper, China, etc. Thus, in Guntner's "Catalogue of Fishes of sh Museum". London (published 1859–1870, in 8 Vols.), the latter countries are mentioned, but no mention is made in Chosen.

beginning of the investigation concerning fishes in Chosen was made S. M. Herzenstein in his "Ichthyologische Bemerkungen aus dem d. K. Akad. d. Wiss. Melanges Biol., tires du Bulletin Acad. Sci. III, pp. 230–233", and then in the same year by F. Steindachner

in his "Ueber einige neue u. seltene Fischarten aus d. ichthyol. Saml Hofmuseum Wien. Denkschr. Akad. Wiss. Wien, Math.-Nat. Cl., LIX, 384".

In the former's paper, a fish found at Pungtung, the central part of was announced as a new genus and species as follows:—

(1) *Pungtungia herzi* HERZENSTEIN

In the latter's paper 12 species found in the neighbourhood of Ke mentioned, among which he describes *Acheilognathus coreanus* as a new s

(2) *Acheilognathus coreanus* STEINDACHNER

(3) *Opsariichthys bidens* GUNTHER

(4) *Barbus schlegeli* GUNTH. = *Hemibarbus labeo* PALLAS

(5) *Silurus asotus* L. = *Parasilurus asotus* (L.)

(6) *Cyprinus carpio* L.

(7) *Culter ilischaeformis* BLEEKER = *C. erythropterus* BASILEWSKY

(8) *Squaliobarbus curriculus* RICHARDSON

(9) *Ophicephalus argus* CANTOR

(10) *Macrones longirostris* GUNTH. = *Leiocassis dumerili* BLEEKER

(11) *M. fulvidraco* RICH. = *Pelteobagrus fulvidraco* RICHARDSON

(12) *Anguilla vulgaris* C. & V. = *A. japonica* (T. & S.)

(13) *Macropodus viridiauratus* LACEP. = *M. chinensis* (BLOCH)

**2.** In 1896 S. M. HERZENSTEIN described, in his "Ueber einige neue u. selt Fische d. Zool. Mus. d. K. Akad. d. Wiss: Ann. Mus. Zool. Petersb., I, pp. 1– a specimen which was collected in the above mentioned Pungtung, as a genus and species as follows:—

(14) *Coreoperca herzi* HERZENSTEIN

**3.** In 1905 L. S. BERG, in his "On the Distribution of *Cottus poecilopu* Siberia (text in Russian):" Trav. Sect. Troitskosawk-Kiaktha Soc. Russ. Geogr., VII, Livr. I, pp. 78–92, reported that the following species was d tributed in Pungtung:—

(15) *Cottus poecilopus* HECKEL

**4.** In 1905 D. S. JORDAN & E. C. STARKS, in their "On a Collection of Fish made in Korea, by P. L. J[illegible], with Descriptions of New Species:" Proc. U. S Nat. Mus., XXVIII, pp. 193–212, mentioned 71 species of fishes, 29 of whic being freshwater fishes.

Among the latter they proposed three new genera, *Longurio, Fusania,* an *Coreius.* But Longurio is synonymous with *Saurogobio,* and *Fusania,* wit *Aphyocypris.* They also listed a name of *Anabas oligolepis,* but I think the have mistaken *Macropodus chinensis* for it. According to the paper, addition species to freshwater fishes in Chosen are as follows:—

(16) *Plecoglossus altivelis* T. & S.

(17) *Carassius auratus* (L.)

(18) *Ochetobius lucens* JORDAN & STARKS

(19) *Longurio athymius* JORDAN & STARKS = *Saurogobio dabryi* BLEEKE

(20) *Coreius cetopsis* (KNER)

(21) *Zacco temmincki* (T. & S.)

(22) *Fusania ensarca* JORDAN & STARKS = *Aphyocypris chinensis* GÜNTH

(23) *Leuciscus hakonensis* GÜNTHER
(24) *L. taczanowskii* STEIND. = *L. brandti* (DYBOWSKI)
(25) *L. semotilus* JORDAN & STARKS = *Phoxinus semotilus* (JORDAN & STARKS)
(26) *Parapelecus jouyi* JORDAN & STARKS
(27) *Culter recurviceps* (RICH.)
(28) *Misgurnus anguillicaudatus* (CANTOR)
(29) *Cobitis taenia* L.
(30) *Elxis coreanus* JORDAN & STARKS = *Lefua costata* (KESSLER)
(31) *Aplocheilichthys latipes* (T. & S.) = *Aplocheilus latipes* (T. & S.)
(32) *Pygosteus sinensis* (GUICHENOT) = *Pungitius sinensis* (GUICH.)
(33) *Hyporhamphus sajori* (T. & S.)
(34) *Mugil cephalus* L.
(35) *Trachydermus ansatus* (RICH.) = *T. fasciatus* HECKEL
(36) *Chaenogobius macrognathus* (BLEEKER)
(37) *Acanthogobius flavimanus* (T. & S.)
(38) *A. hasta* (T. & S.)
(39) *Tridentiger obscurus* (T. & S.)
(40) *T. bifasciatus* (STEIND.)

5. In 1906 L. S. BERG, in his "Description of a new species of *Leucogobio* from Korea:" Ann. Mag. Nat. Hist. (7), XVIII, pp. 394–396, described the following species as new:—

(41) *Leucogobio coreanus* BERG

6. In 1907 L. S. BERG, in his "Description of a new Cyprinoid Fish, *Acheilognathus signifer*, from Korea, with a Synopsis of all the known *Rhodeina*:" Ann. Mag. Nat. Hist. (7), XIX, pp. 159–193, made public a new species:—

(42) *Acheilognathus signifer* BERG

But this should be a subspecies to *A. lanceolata* (T. & S.)

7. In 1907 again L. S. BERG, in his "Revision des Poissons d'eau douce de la Corre:" Ann. Mus. Zool. Acad. Sci. St. Petersb., XII, pp. 1–12, published 44 species of freshwater fishes in a body. This is the beginning of a paper in a collected form concerning the freshwater fishes in Chosen. According to this paper, additional species are as follows:—

(43) *Ladislavia taczanowskii* DYBOWSKI
(44) *Barbus mylodon* BERG = *Belligobio mylodon* (BERG)
(45) *Phoxinus lagowskii* DYB.
(46) *Nemacheilus barbatulus toni* (DYB.) = *Barbatula toni* (DYB.)
(47) *Siniperca chuatsi* BASI. = *S. scherzeri* STEIND.

8. In 1908 T. REGAN, in his "A Collection of Freshwater Fishes from Corea:" P. Z. S. London, pp. 59–63, published 11 species of freshwater fishes in Chosen, out of which 7 new species are described. Among the latter, however, *Silurus bedfordi* is a synonym of *Parasilurus asotus*, and *Ctenogobius bedfordi*, of *Rhinogobius similis*. According to the above paper, additional species are as follows:—

(48) *Pseudorasbora parva* T. & S.
(49) *Barilius platypus* (T. & S.) = *Zacco platypus* (T. & S.)

(50) *Leucogobio strigatus* REGAN
(51) *Acanthogobio longirostris* REGAN = *Hemibarbus longirostris* (REGAN)
(52) *Acanthorhodeus gracilis* REGAN
(53) *Liobagrus andersoni* REGAN
(54) *Odontobutis potamophilus* GUNTH. = *Eleotris potamophila* (GUNTH.)
(55) *Tridentiger coreanus* REGAN
(56) *Ctenogobius bedfordi* REGAN = *Rhinogobius similis* (GILL)

**9.** In 1909 L. S. BERG, in his "Ichthyologia Amurensis:" Mem. l'Acad. Imp. Sci. St. Petersburg, (8), XXIV, No. 9, pp. 26–27, reported that the following species were distributed in Chosen:—

(57) *Oncorhynchus gorbuscha* (WALBAUM)
(58) *O. keta* (WALBAUM)

**10.** In 1911 S. TANAKA, in his "On some freshwater Fishes from Chosen" (text in Japanese): Zool. Mag. Tokyo, XXIII, pp. 107–108, treated 6 species, which included no unrecorded species.

**11.** In 1913 D. S. JORDAN and C. W. METZ, in their "A catalogue of the fishes known from the waters of Korea:" Mem. Carneg. Mus., VI, No. 2, pp. 1–65, published a catalogue of 254 species of fishes produced in Chosen, among which 75 are freshwater fishes. Among the latter, there are three species proposed by them as new, *Pseudaspius modestus, P. bergi,* and *Rhodeus chonsenicus*. But the former two are sure to be synonymous with *Phoxinus oxycephalus,* and the latter is mistaken for *Aphyocypris chinensis* appearently. Additional species given in this paper are as follows:—

(59) *Coilia nasus* T. & S.
(60) *C. ectenes* JORDAN & SEALE
(61) *Oncorhynchus masou* (BREV.)
(62) *Osmerus dentex* STEINDACHNER
(63) *Spirinchus verecundus* JORDAN & METZ
(64) *Salanx hyalocranius* ABBOTT = *Protosalanx hyalocranius* (ABBOTT).
(65) *Pseudogobio esocinus* T. & S.
(66) *P. rivularis* (BASI.) = *Abbottina rivularis* (BASI.)
(67) *Acanthorhodeus asmussi* DYB.
(68) *Rhodeus ocellatus* GÜTNHER
(69) *Pseudoperilampus hondae* JORDAN & METZ
(70) *Parapelecus eigenmanni* JORDAN & METZ
(71) *Pseudaspius bergi* JORDAN & METZ } = *Phoxinus oxycephalus* BLEEKER
*P. modestus* JORDAN & METZ }
(72) *Monopterus albus* (ZUIEW) = *Fluta alba* (ZUIEW)
(73) *Liza haematochila* (T. & S.)
(74) *Lateolabrax japonicus* (C. & V.)
(75) *Platycephalus indicus* (GMELIN)
(76) *Odontobutis obscurus* (T. & S.)
(77) *Ctenogobius hadropterus* (JORDAN & SNYDER) = *Rhinogobius giurinus* (RUTTER)

**12.** In 1914 L. S. BERG, in his "Les poissons du fleuve Toumenoula (Corée), collectionés par A. L. CZERSKI" (text in Russian): Ann. Mus. Zool. Acal. Imp.

Sci. St. Petersb., XIX, pp. 554–561, described 43 species of fishes at the estuary of the Toman River, 25 of which being freshwater fishes. Among the latter, those that should be newly added are as follows:—

(78) *Lampetra fluviatilis japonica* (MARTENS)
(79) *Mesopus olidus* (PALL.) = *Hypomesus olidus* (PALL.)
(80) *Salangichthys microdon* BLEEKER
(81) *Leuciscus waleckii* (DYB.)
(82) *Phoxinus percnurus mantschuricus* BERG
(83) *Gobio gobio* L.
(84) *Rhodeus sericeus* (PALL.)
(85) *Gasterosteus aculeatus* L.
(86) *Myoxocephalus jaok* (C. & V.)
(87) *Cottus czerskii* BERG
(88) *Percottus glehni* DYB.

**13.** In 1917 I. GINSBURG, in his "On two species of fishes from the Yalu River, China:" Proc. U. S. Nat. Mus., LIV, pp. 99–101, described two species, among which *Rhinogobius sowerby* is given as a new species, but this is synonymous with *R. similis*.

**14.** In 1918 T. KAWAMURA, in his "A sketch of the distribution of freshwater animals, including freshwater fishes, in Eastern Asia:" Nippon Tansui Seibutsugaku or Freshwater Biology of Japan. Part II, pp. 475–485, gives a general account of freshwater fishes in Eastern Asia, in which, according to him, Chosen in the North-Eastern Part belongs to the Holarctic Region and the rest of Chosen is a zone where Holarctic and Oriental types are mixed.

**15.** In 1921 A. C. SOWERBY, in his "On a new Siluroid Fish from the Yalu River, S. Manchuria:" Proc. U. S. Nat. Mus., Vol. LX, pp. 1–2, published a new species as follows:—

(89) *Pseudobagrus emarginatus* SOWERBY

**16.** In 1923 T. MORI, in his "A check list of Korean Vertebrates (A Catalogue of the Exhibition of Korean Natural History Specimens, issued by the Chosen Natural History Society)", published a list of 102 species of freshwater fishes, of which new additions are as follows:—

(90) *Lampetra mitsukuri* (HATTA) = *L. reissneri* (MARTENS)
(91) *Acipenser ? mantschuricus* BASI. = *A. sinensis* GRAY
(92) *Pseudobagrus vacheli* (RICH.)
(93) *Liobagrus ? reini* HILG. = *L. mediadiposalis* MORI
(94) *Hemiculter leucisculus* (BASI.)
(95) *Misgurnus decemcirrosus* (BASI.) = *M. mizolepis* GUNTHER
(96) *Anguilla mauritiana* BENNET
(97) *Parasalanx ariakensis* KISHINOUYE
(98) *Neosalanx iwasei* WAKIYA & TAKAHASHI = *N. andersoni* RENDAHL
(99) *Coreoperca kawamebari* (T. & S.)
(100) *Periophthalmus cantonensis* (OSBECK)
(101) *Spheroides ocellatus* (OSBECK)

**17.** In 1925 D. S. JORDAN & C. L. HUBBS, in their "Record of fishes obtained by Dr. S. JORDAN in Japan, 1922:" Mem. Carneg. Mus., X, No. 2, pp. 93–346,

published four new species found in Heijo, i.e., *Gnathopogon majimae, G. longifilis, G. tsuchigae,* and *Sarcocheilichthys Morii.* But of the four, *G. longifilis* being a synonym to *G. majimae* and *G. tsuchigae* a synonym to *Leucogobio coreanus,* what should be newly added are the following two:—

(102) *Gnathopogon majimae* JORDAN & HUBBS = *Leucogobio majimae* (JORDAN & HUBBS)

(103) *Sarcocheilichthys morii* JORDAN & HUBBS

**18.** In 1925 S. TANAKA, in his "Figures and descriptions of the fishes of Japan: XXXIV, pp. 636–461", published a new species found in Chosen, which is as follows:—

(104) *Siniperca aequiformis* TANAKA

**19.** In 1925 T. MORI, in his "Freshwater Fishes and Rhopalocera in the highland of South Kankyodo, Korea, (text in Japanese):" Journ. Chosen Nat. Hist. Soc., No. 3, pp. 54–57, listed 15 species of freshwater fishes living in the upper reaches of the Yalu, dwelling upon the resemblance between them and the fish-fauna of the upper reaches of the Amur. This report makes the following new additions to Chosen:—

(105) *Brachymystax lenok* (PALL.)

(106) *Lota lota* L.

**20.** In 1927 C. D. REEVES, in his "On the Catalogue of Fishes in Northern China and Korea:" Journ. Pan Paci. Resear. Inst., XI, No. 3, pp. 1–16, made mention of 41 species of freshwater fishes in Chosen, but all are already known species.

**21.** In 1927 T. MORI, in his "On the fishes from Seiko (West Lake), near Suigen, Chosen" (text in Japanese): Journ. Chosen Nat. Hist. Soc., No. 5, pp. 54–56, made mention of 26 species, all of which however, are already known species.

**22.** In 1927 T. MORI, in his "On the freshwater fishes from the Yalu River, with descriptions of new species:" Journ. Chosen Nat. Hist. Soc., No. 6, pp. 8–24, described 49 species of fishes living in the Yalu River. Of the above species, five new to science and which should be newly added are as follows:—

(107) *Hucho ishikawae* MORI

(108) *Thymallus arcticus jaluensis* MORI

(109) *Pseudogobio yaluensis* MORI = *Microphysogobio yaluensis* (MORI)

(110) *Sarcocheilichthys soldatovi* (BERG)

(111) *Acheilognathus yamatsutae* MORI

**23.** In 1927 T. MORI, in his "Notes on the genus *Sarcocheilichthys,* with the descriptions of four new species:" Annot. Zool. Japon., XI, No. 2, pp. 97–106, mentioned 11 species belonging to the genus *Sarcocheilichthys.* Among them there are three new species in Chosen, one of which, i.e. *S. koreensis,* is synonymous to *S. morii.* So the following two are newly added:—

(112) *Sarcocheilichythys kobayashii* MORI

(113) *S. wakiyae* MORI

**24.** In 1928 T. MORI, in his "A Catalogue of Fishes of Korea:" Journ. Pan. Paci. Resear. Inst., III, No. 3, pp. 3–8, listed 386 species, 118 of which being freshwater fishes. Additional species are as follows:—

(114) *Acipenser mikadoi* HILGENDORF
(115) *Leiocassis ussuriensis* (DYB.)
(116) *Barbatula intermedia* (KESSLER)
(117) *Culter brevicauda* GUNTHER
(118) *Pungitius brevispinosus* (OTAKI)

**25.** In 1929 Y. WAKIYA and T. MORI, in their "On two new Loaches of the genus *Cobitis* from Corea:" Journ. Chosen Nat. Hist. Soc., No. 9, pp. 31–33, published the following two new species:—

(119) *Cobitis multifasciata* WAKIYA & MORI
(120) *C. rotundicauda* WAKIYA & MORI

**26.** In 1930 T. MORI, in his "On the freshwater fishes from the Tumen River, Korea, with the descriptions of new species:" Journ. Chosen Nat. Hist. Soc., No. 11, pp. 39–49, described 39 species, out of which he proposed 4 new species. According to this report, additional species are as follows:—

(121) *Brachymystax tumensis* MORI
(122) *Mallotus elongatus* MORI
(123) *Phoxinus phoxinus* (L.)
(124) *Moroco oxyrhynchus* MORI = *Phoxinus oxyrhynchus* (MORI)
(125) *Cottus hangiongensis* MORI
(126) *Mugil oeur* FORSKAL

**27.** In 1931 L. S. BERG, in his "A review of the Lampreys of the Northern Hemisphere:" Ann. Mus. Zool. Acad. Sci. L'U. R. S. S., XXXII, pp. 87–116, published a new species occuring in the Yalu River, as follows:—

(127) *Lampetra morii* BERG

**28.** In 1934 T. MORI and K. UCHIDA, in their "A revised Catalogue of Fishes of Korea, Journ. Chosen Nat. Hist. Soc., No. 19, pp. 12–33", made mention of 523 species. On these number, 136 are freshwater fishes. According to this catalogue, additional species are as follows:—

(128) *Salverinus leucomaenis* (PALL.) = *S. malma* (WALB.)
(129) *Brachymystax coregonoides* PALLAS
(130) *Hypomesus japonicus* (BREV.)
(131) *Sarcocheilichthys lacustris* (DYB.)
(132) *Pungtungia hilgendorfi* (ISHIKAWA)
(133) *Acanthorhodeus rhombeum* (T. & S.) = *Paracheilognathus pseudorhombea* MORI
(134) *Gobiobotia macrocephalus* MORI
(135) *Microphysogobio koreensis* MORI
(136) *Pungitius tymensis* (NIKOLSKY)

**29.** In 1934 L. S. BERG, in his "Zoogeographical divisions for freshwater fishes of the Pacific slope of N. Asia:" Proc. Fifth Paci. Sci. Congr., V, pp. 3791–3793, suggests that Chosen should belong to the Amur Transitional Region and is divided into two parts: (a) the eastern part, Fusan on the southern end, with rivers flowing into the Japan Sea, which belongs to the Maritime District, (b) the rest of Chosen, that is, Chosen minus the above mentioned part, which belongs to the West Korea-South Manchuria Province.

**30.** In 1935 T. MORI, in his "Notes o Korean *Rhodeina*" (text in Japanese).

Zool. Mag. Japan, XLVII, pp. 559–574, described 15 species belonging to *Rhodeina* of Chosen, of which three were new to science, and two unrecorded. Among the new species, *Paracheilognathus pseudorhombea* having been mentioned in the preceding catalogue (§ 27) under the name *Acanthorhodeus rhombeum*, I will omit mentioning it here; the remaining four are as follows:—

(137) *Pseudoperilampus uyekii* MORI = *Rhodeus uyekii* (MORI)

(138) *P. suigensis* MORI = *Rhodeus suigensis* (MORI)

(139) *P. notatus* (NICHOLS) = *Rhodeus notatus* NICHOLS

(140) *Paracheilognathus tabira* (JORDAN & THOMPSON)

**31.** In 1935 T. MORI, in his "On the Geographical Distribution of Korean Salmonoid Fishes:" Bull. Biogeogr. Soc. Japan, VI, No. 1, pp. 1–9, wrote on the distribution of 21 species belonging to Korean Salmonoid fishes. He should make the following corrections of their specific names, in accordance with Berg's recent book "Les poissons des eaux douces de la R. S. S. R. (1933).

*Salverinus fariopsis* STEINDACHNER into *S. malma curilus* (PALLAS),

*Oncorhynchus macrostomus* GÜNTHER into *O. masou macrostoma* GÜNTHER.

**32.** In 1935 T. MORI, in his "Descriptions of two new Genera and seven new Species of *Cyprinidae* from Chosen:" Annot. Zool. Japon., XV., pp. 161–175, established two new genera and seven new species. Of these species, *Gobiobotia macrocephalus* and *Microphysogobio koreensis* having been mentioned in the preceding catalogue (§ 29), the following five are newly added:—

(141) *Pseudopungtungia nigra* MORI

(142) *Coreoleuciscus splendidus* MORI

(143) *Gobiobotia brevibarba* MORI

(144) *G. naktongensis* MORI

(145) *Microphysogobio longidorsalis* MORI

**33.** I have now at hand, though not yet published, the following three new species, and two unrecorded species:—

(146) *Acanthorhodeus ommaturus* (RICH.)

(147) *Cottus shiragiensis* MORI

(148) *Leiocassis brashnikovi* BERG

(148) *Parasilurus microdorsalis* MORI

(150) *Pseudobagrus brevicorpus* MORI

Summarizing the papers and reports by the above students and arranging these in due order and form, we get a total of 150 species of freshwater fishes.

## III Zoogeographical Distribution

As above stated, there are 150 species of freshwater fishes in Chosen. Through my investigations extending over nearly fifteen years, I have been able to make out a table showing how these species are distributed in various rivers in Chosen. The table is as follows:—

## Table I

### List of the distribution of freshwater fishes in Chosen

| Specific names | Rivers flowing into the Japan Sea in N. & S. Kankyodo | | | | | | Rivers flowing west into the Yellow Sea | | | | | Rivers flowing south | | | Rivers flowing east (except Kankyodo) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R. N. Nandai | R. Toman | R. S. Nandai | R. Josen | R. Ryuko | R. Anpen | R. Oryoku | R. Seisen | R. Daido | R. Kan | R. Kin | R. Eizan | R. Senshin | R. Rakuto | Urchin | R. Sekiheki |
| Family ***Petromyzontidae*** | | | | | | | | | | | | | | | | |
| *Lampetra japonica* (MARTENS) | + | + | + | + | + | + | – | – | – | – | – | – | – | + | + | – |
| *L. reissneri* DYBOWSKI | + | + | + | + | + | + | – | – | – | – | + | – | – | – | + | – |
| *L. morii* BERG | – | – | – | – | – | – | + | + | + | + | – | – | – | – | – | – |
| Family ***Acipenseridae*** | | | | | | | | | | | | | | | | |
| *Acipenser mikadoi* HILGONDORF | + | + | + | + | – | + | – | – | – | – | – | – | – | – | – | – |
| *A. sinensis* GRAY | – | – | – | – | – | – | + | – | + | + | – | – | – | – | – | – |
| Family ***Engraulidae*** | | | | | | | | | | | | | | | | |
| *Coilia nasus* (T. & S.) | – | – | – | – | – | – | – | – | – | + | – | – | – | + | – | – |
| *C. ectenes* JORDAN & SEALE | – | – | – | – | – | – | + | – | + | – | + | + | – | – | – | – |
| Family ***Salmonidae*** | | | | | | | | | | | | | | | | |
| *Oncorhynchus masou* (BREVOORT) | + | + | + | + | + | + | – | – | – | – | – | – | – | + | + | – |
| *O. masou macrostoma* GÜNTHER | + | + | + | + | + | + | – | – | – | – | – | – | – | – | + | – |
| *O. keta* (WALBAUM) | + | + | + | + | + | + | – | – | – | – | – | – | – | + | + | + |
| *O. gorbuscha* (WALB.) | + | + | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| °*Hucho ishikawae* MORI | – | – | – | – | – | – | + | – | – | – | – | – | – | – | – | – |
| *Salverinus malma* (WALB.) | + | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *S. malma curilus* (PALLAS) | + | + | + | + | + | – | + | + | + | – | – | – | – | – | – | – |
| Family ***Coregonidae*** | | | | | | | | | | | | | | | | |
| *Brachymystax lenok* PALLAS | – | – | – | – | – | – | + | + | + | + | – | – | – | – | – | – |
| *B. coregonoides* PALLUS | – | – | – | – | – | – | + | – | – | – | – | – | – | – | – | – |
| °*B. tumensis* MORI | + | + | + | + | – | – | – | – | – | – | – | – | – | – | – | – |
| Family ***Thymallidae*** | | | | | | | | | | | | | | | | |
| °*Thymallus jaluensis* MORI | – | – | – | – | – | – | + | – | – | – | – | – | – | – | – | – |
| Family ***Plecoglossidae*** | | | | | | | | | | | | | | | | |
| *Plecoglossus altivelis* T. & S. | – | – | – | – | – | + | + | + | – | + | – | – | + | + | + | + |
| Family ***Osmeridae*** | | | | | | | | | | | | | | | | |
| *Osmerus dentex* STEINDACHNER | + | + | + | + | + | + | – | – | – | – | – | – | – | – | – | – |
| °*Spirinchus verecundus* JORD. & METZ | + | + | + | + | – | – | – | – | – | – | – | – | – | – | – | – |
| *Hypomesus olidus* (PALLAS) | + | + | + | + | + | + | – | – | – | – | – | – | – | – | – | – |
| *H. japonicus* (BREV.) | – | – | – | – | + | + | – | – | – | – | – | – | – | – | – | – |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| °*Mallotus elongatus* MORI | + | − | − | − | − | − | − | − | − | − | − | − | − | − | − | − |
| Family ***Salangidae*** | | | | | | | | | | | | | | | | |
| *Salangichthys microdon* BLEEKER | + | + | + | + | + | + | − | − | − | − | − | − | − | + | + | + |
| *Salanx ariakensis* KISHINOUYE | − | − | − | − | − | − | + | + | + | + | + | + | + | + | − | − |
| *Protosalanx hyalocranius* ABBOTT | − | − | − | − | − | − | + | + | + | + | + | − | − | − | − | − |
| *Neosalanx andersoni* RENDAHL | − | − | − | − | − | − | + | + | + | + | + | + | − | − | − | − |
| Family ***Siluridae*** | | | | | | | | | | | | | | | | |
| *Parasilurus asotus* L. | − | − | − | − | − | − | + | + | + | + | + | + | + | + | − | − |
| °*P. microdorsalis* MORI | − | − | − | − | − | + | + | + | − | + | − | − | − | + | + | + |
| Family ***Bagridae*** | | | | | | | | | | | | | | | | |
| *Pelteobagrus fulvidraco* (RICH.) | − | − | − | − | − | − | + | + | + | + | + | + | + | + | − | − |
| *Pseudobagrus vacheli* (RICH.) | − | − | − | − | − | − | + | − | + | + | − | − | − | + | − | − |
| °*P. emarginatus* SOWERBY | − | − | − | − | − | − | + | − | + | + | − | − | − | − | − | − |
| °*P. brevicorpus* MORI | − | − | − | − | − | − | − | − | − | − | − | − | − | + | − | − |
| *Leiocassis dumerili* BLEEKER | − | − | − | − | − | − | − | + | + | + | + | − | − | − | − | − |
| *L. ussuriensis* (DYB.) | − | − | − | − | − | − | + | + | + | + | − | − | − | − | − | − |
| *L. brashnikowi* BERG | − | − | − | − | − | − | − | − | + | + | + | − | − | − | − | − |
| °*Liobagrus andersoni* REGAN | − | − | − | − | − | − | − | + | + | + | − | − | − | − | + | + |
| °*L. mediadiposalis* MORI | − | − | − | − | − | − | − | − | − | − | + | + | + | + | − | − |
| Family ***Cyprinidae*** | | | | | | | | | | | | | | | | |
| Subfamily ***Cyprininae*** | | | | | | | | | | | | | | | | |
| *Cyprinus carpio* L. | + | − | − | − | − | − | + | + | + | + | + | + | + | + | + | + |
| *Carassius auratus* (L.) | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| *C. auratus gibelio* (BLOCH) | + | + | − | − | − | − | − | − | − | − | − | − | − | − | − | − |
| Subfamily ***Gobioninae*** | | | | | | | | | | | | | | | | |
| *Hemibarbus labeo* (PALLUS) | − | − | − | − | − | − | + | + | + | + | + | + | + | + | − | − |
| *H. longirostris* (REGAN) | − | − | − | − | − | − | + | + | + | + | + | − | + | + | − | − |
| °*Belligobio mylodon* (BERG) | − | − | − | − | − | − | − | − | − | + | − | − | − | − | − | − |
| *Pseudogobio esocinus* (T. & S.) | − | − | − | − | − | − | + | + | + | + | + | + | + | + | + | − |
| *Abbottina rivularis* (BASILEWSKY) | − | − | − | − | − | − | − | − | − | + | + | + | − | − | − | − |
| *Leucogobio strigatus* REGAN | − | − | − | − | − | − | + | + | + | + | + | − | + | − | − | − |
| °*L. coreanus* BERG | − | − | − | − | − | − | + | + | + | + | + | − | + | + | − | − |
| °*L. majimae* (JORD. & HUBBS) | − | − | − | − | − | − | + | − | + | − | − | − | − | − | − | − |
| *Pseudorasbora parva* T. & S. | + | − | − | + | − | − | + | + | + | + | + | + | + | + | − | − |
| *Ladislavia taczanowskii* DYB. | − | − | − | − | − | − | + | + | + | + | − | − | − | − | − | − |
| °*Sarcocheilichthys morii* JORD. & HUBBS | − | − | − | − | − | − | − | − | + | + | + | − | + | − | − | − |
| °*S. kobayashii* MORI | − | − | − | − | − | − | − | − | − | − | − | − | − | + | − | − |
| °*S. wakiyae* MORI | − | − | − | − | − | − | − | − | − | − | − | − | + | − | − | − |
| *S. soldatovi* (BERG) | − | − | − | − | − | − | + | + | − | − | − | − | − | − | − | − |
| *S. lacustris* (DYB.) | − | − | − | − | − | − | + | − | − | − | − | − | − | − | − | − |
| *Gobio gobio* L. | + | + | + | + | + | + | + | − | − | − | − | − | − | − | − | − |
| *G. gobio macrocephalus* MORI | + | + | − | − | − | − | − | − | − | − | − | − | − | − | − | − |
| *Coreius cetopsis* (KNER.) | − | − | − | − | − | − | − | − | − | + | − | − | − | − | − | − |
| °*Pungtungia herzi* HERZENSTEIN | − | − | − | − | − | − | + | + | + | + | + | − | + | + | − | − |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *P. hilgendorfi* (Ishikawa) | — | — | — | — | — | — | — | — | — | — | — | — | + | — | — | — |
| °*Pseudopungtungia nigra* Mori | — | — | — | — | — | — | — | — | — | — | + | — | — | — | — | — |
| Subfamily ***Leuciscinae*** | | | | | | | | | | | | | | | | |
| *Aphyocypris chinensis* Günther | — | — | — | — | — | — | + | — | + | + | + | + | + | — | — | — |
| *Leuciscus waleckii* (Dyb.) | + | + | — | — | — | — | + | — | — | — | — | — | — | — | — | — |
| *L. waleckii tumensis* Mori | + | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *L. brandti* (Dyb.) | + | — | — | — | — | + | — | — | — | — | — | — | — | + | + | — |
| *L. hakonensis* (Günther) | — | + | — | + | — | — | — | — | — | — | — | + | + | + | — | + |
| °*Phoxinus semotilus* (Jord. & Starks) | — | — | — | + | + | + | — | + | + | + | — | — | — | — | — | + |
| *Ph. lagowskii* (Dyb.) | + | + | + | + | + | + | — | — | — | — | — | — | — | — | — | + |
| *Ph. oxycephalus* (Blecker) | + | — | — | — | — | — | + | + | + | + | + | — | + | + | + | + |
| °*Ph. oxyrhynchus* (Mori) | + | + | + | + | — | — | — | — | — | — | — | — | — | — | — | — |
| *Ph. percnurus sachalinensis* (Berg) | + | — | — | + | — | — | — | — | — | — | — | — | — | — | — | — |
| *Ph. phoxinus* L. | + | + | + | + | — | — | + | — | — | — | — | — | — | — | — | — |
| °*Coreoleuciscus splendidus* Mori | — | — | — | — | — | — | — | — | — | + | + | — | + | + | + | — |
| *Opsariichthys bidens* Gunther | — | — | — | — | — | — | + | + | + | + | + | + | + | + | — | — |
| *Zacco platypus* (T. & S.) | — | — | — | — | — | — | + | + | + | + | + | + | + | + | + | + |
| *Z. temmincki* (T. & S.) | — | — | — | — | — | — | + | + | + | + | + | + | + | + | + | — |
| *Squaliobarbus curriculus* (Rich.) | — | — | — | — | — | — | — | — | + | + | — | — | — | — | — | — |
| °*Ochetobius lucens* (Jord. & Starks) | — | — | — | — | — | — | — | — | — | + | — | — | — | — | — | — |
| Subfamily ***Abramidinae*** | | | | | | | | | | | | | | | | |
| °*Parapelecus jouyi* (Jord. & Starks) | — | — | — | — | — | — | — | — | — | + | — | — | — | — | — | — |
| *P. eigenmanni* (Jord. & Metz) | — | — | — | — | — | — | — | — | — | + | + | — | — | — | — | — |
| *Culter erythropterus* Basi. | — | — | — | — | — | — | + | — | + | + | + | — | — | + | — | — |
| *C. recurviceps* (Rich.) | — | — | — | — | — | — | — | — | — | + | — | — | — | — | — | — |
| *C. brevicauda* Günther | — | — | — | — | — | — | — | — | + | + | — | — | — | + | — | — |
| *Hemiculter leucisculus* (Basi.) | — | — | — | — | — | — | — | — | + | + | + | + | — | — | — | — |
| Subfamily ***Achilognathinae*** | | | | | | | | | | | | | | | | |
| *Acheilognathus lanceolata signifer* Berg | — | — | — | — | — | — | — | — | + | + | — | — | + | + | — | — |
| *A. lanceolata intermedia* (T. & S.) | — | — | — | — | — | — | + | — | + | + | + | + | — | + | — | — |
| °*A. yamatsutae* Mori | — | — | — | — | — | — | + | — | + | + | — | + | + | + | — | — |
| *Acanthorhodeus asmussi* Dyb. | — | — | — | — | — | — | — | + | + | + | + | — | + | + | — | — |
| *A. asmussi bergi* Mori | — | — | — | — | — | — | + | — | — | — | — | — | — | — | — | — |
| °*A. gracilis* Regan | — | — | — | — | — | — | — | — | — | + | + | + | + | — | — | — |
| °*Paracheilognathus coreanus* (Steind.) | — | — | — | — | — | — | — | — | — | + | + | — | — | + | — | — |
| °*P. pseudorhombea* Mori | — | — | — | — | — | — | — | — | — | + | + | — | + | + | — | — |
| *P. tabira* (Jord. & Thompson) | — | — | — | — | — | — | — | — | — | + | — | — | — | — | — | — |
| *Rhodeus ocellatus* (Kner) | — | — | — | — | — | — | — | — | — | + | + | — | + | + | — | — |
| *Rh. sericeus* (Pall.) | + | + | + | + | + | — | — | — | — | — | — | — | — | — | — | — |
| *Rhodeus notatus* Nichols | — | — | — | — | — | — | — | + | — | — | — | — | — | — | — | — |
| °*Rh. uyekii* (Mori) | — | — | — | — | — | — | — | — | — | + | + | — | — | + | — | — |
| °*Rh. suigensis* (Mori) | — | — | — | — | — | — | — | — | — | + | + | — | — | — | — | — |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| °*Pseudoperilampus hondae* JORD. & METZ | — | — | — | — | — | — | — | — | — | + | — | — | — | — | — | — |
| Subfamily ***Gobiobotinae*** | | | | | | | | | | | | | | | | |
| *Saurogobio dabryi* BLEEKER | — | — | — | — | — | — | — | — | + | + | — | — | — | — | — | — |
| °*Gobiobotia macrocephalus* MORI | — | — | — | — | — | — | — | — | — | + | — | — | — | — | — | — |
| °*G. brevibarba* MORI | — | — | — | — | — | — | — | — | — | + | — | — | — | — | — | — |
| °*G. naktongensis* MORI | — | — | — | — | — | — | — | — | — | — | — | — | — | + | — | — |
| °*Microphysogobio koreensis* MORI | — | — | — | — | — | — | — | — | — | + | + | + | + | + | — | — |
| °*M. longidorsalis* MORI | — | — | — | — | — | — | — | — | — | + | + | — | — | — | — | — |
| °*M. yaluensis* (MORI) | — | — | — | — | — | — | + | — | — | — | — | — | — | — | — | — |
| Subfamily ***Cobitinae*** | | | | | | | | | | | | | | | | |
| *Cobitis taenia* L. | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| °*C. multifasciata* WAKIYA & MORI | — | — | — | — | — | — | — | — | — | — | — | — | — | + | — | — |
| °*C. rotundicauda* WAKIYA & MORI | — | — | — | — | — | — | — | — | — | + | + | — | — | + | — | — |
| *Misgurnus anguillicaudatus* (CANT.) | + | — | — | — | — | — | + | + | + | + | + | + | + | + | — | — |
| *M. mizolepis* GÜNTHER | — | — | — | — | — | — | — | — | — | + | + | + | — | + | — | — |
| *Lefua costata* KESSLER | + | + | — | + | + | + | — | — | + | + | — | + | — | — | + | + |
| *Barbatula toni* (DYB.) | + | + | + | + | + | + | + | + | + | + | — | — | — | + | + | + |
| *B. intermedia* (KESSLER) | + | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Family ***Flutidae*** | | | | | | | | | | | | | | | | |
| *Fluta alba* (ZUIEW) | — | — | — | — | — | — | + | + | + | + | + | + | + | + | — | — |
| Family ***Anguillidae*** | | | | | | | | | | | | | | | | |
| *Anguilla japonica* (T. & S.) | — | — | — | — | — | — | + | + | + | + | + | + | + | + | + | + |
| *A. mauritiana* BENNET | — | — | — | — | — | — | — | — | — | — | — | Saishu | — | — | — | — |
| Family ***Cyprinodontidae*** | | | | | | | | | | | | | | | | |
| *Aplocheilus latipes* (T. & S.) | — | — | — | — | — | — | — | + | + | + | + | + | + | + | + | — |
| Family ***Gasterosteidae*** | | | | | | | | | | | | | | | | |
| *Gasterosteus aculeatus* (L.) | + | + | + | + | + | + | — | — | — | — | — | — | — | + | + | + |
| *Pungitius sinensis* (GUICHE.) | + | + | + | + | + | + | — | — | — | — | — | — | — | — | — | — |
| *P. brevispinosus* (OTAKI) | + | + | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *P. tymensis* (NIKOLSKY) | + | + | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Family ***Osphromenidae*** | | | | | | | | | | | | | | | | |
| *Macropodus chinensis* (BLOCH) | — | — | — | — | — | — | + | + | + | + | + | + | + | + | — | — |
| Family ***Ophicephalidae*** | | | | | | | | | | | | | | | | |
| *Ophicephalus argus* (CANTOR) | — | — | — | — | — | — | + | + | + | + | + | + | + | + | — | + |
| Family ***Mugilidae*** | | | | | | | | | | | | | | | | |
| *Mugil cephalus* L. | + | — | — | — | — | — | — | — | + | + | + | + | — | + | — | — |
| *M. Oeur* FORSKAL | — | — | — | — | — | — | — | — | — | — | — | + | — | + | — | — |
| *Liza haematochila* (T. & S.) | — | — | — | — | — | + | — | + | + | + | + | — | — | + | + | — |
| Family ***Oligoridae*** | | | | | | | | | | | | | | | | |
| *Lateolabrax japonicus* (C. & V.) | + | — | — | — | — | + | + | + | + | + | + | + | + | + | + | — |
| Family ***Epinephelidae*** | | | | | | | | | | | | | | | | |
| °*Coreoperca herzi* HERZENSTEIN | — | — | — | — | — | — | + | + | + | + | + | + | + | + | + | — |
| *C. kawamebari* (T. & S.) | — | — | — | — | — | — | — | — | — | — | — | — | + | + | — | — |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| °*Siniperca aequiformis* TANAKA | — | — | — | — | — | — | — | — | — | — | — | — | + | + | — | — |
| *S. scherzeri* STEIND. | — | — | — | — | — | — | + | + | + | + | + | + | — | + | — | — |
| Family ***Tetraodontidae*** | | | | | | | | | | | | | | | | |
| *Spheroides ocellatus* (OSBECK) | — | — | — | — | — | — | + | + | + | + | + | + | — | — | — | — |
| Family ***Cottidae*** | | | | | | | | | | | | | | | | |
| *Cottus poecilopus* HECKEL | + | + | — | — | — | — | + | + | + | + | — | — | — | — | — | — |
| *C. czerskii* BERG | + | + | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| °*C. hangiongensis* MORI | + | + | + | + | + | + | — | — | — | — | — | — | — | — | — | + |
| °*C. shiragiensis* MORI | — | — | — | — | — | — | — | — | — | — | — | — | — | + | — | — |
| *Myoxocephalus jaok* (C. & V.) | + | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Trachydermus fasciatus* HECKEL | — | — | — | + | — | + | + | + | + | + | — | + | — | + | — | — |
| Family ***Platycephalidae*** | | | | | | | | | | | | | | | | |
| *Platycephalus indicus* (L.) | — | — | — | — | — | — | + | — | + | + | + | + | — | + | — | — |
| Family ***Eleotridae*** | | | | | | | | | | | | | | | | |
| *Odontobutis obscurus* (T. & S.) | — | — | — | — | — | — | — | — | + | + | + | + | + | + | — | — |
| *Eleotris potamophila* (GUNTHER) | — | — | — | — | — | — | + | + | + | — | — | — | — | — | — | — |
| *Percottus glehni* (DYB.) | + | + | + | + | — | — | — | — | — | — | — | — | — | — | — | — |
| Family ***Gobiidae*** | | | | | | | | | | | | | | | | |
| *Chaenogobius macrognathus* (BLEEK.) | + | + | + | + | + | + | — | — | — | — | — | — | — | + | + | + |
| *Rhinogobius similis* (GILL) | + | — | — | + | — | + | + | + | — | + | + | — | + | + | + | + |
| *Rh. giurinus* (RUTTER) | + | + | + | + | + | + | — | — | — | + | — | — | + | + | — | — |
| *Tridentiger obscurus* (T. & S.) | + | + | + | + | + | + | — | — | — | + | — | + | — | + | + | + |
| *T. bifasciatus* (STEIND.) | — | — | — | + | — | + | — | — | — | — | — | — | — | + | + | — |
| °*T. coreanus* REGAN | — | — | — | — | — | — | — | — | — | — | + | — | — | — | — | — |
| *Acanthogobius flavimanus* (T. & S.) | — | — | — | + | — | — | — | — | — | — | — | — | — | — | — | — |
| *A. ommaturus* (RICH.) | — | — | — | — | — | — | + | — | + | + | + | — | — | — | — | — |
| *A. hasta* (T. & S.) | — | — | — | — | — | — | — | — | + | + | + | + | — | + | — | — |
| Family ***Gadidae*** | | | | | | | | | | | | | | | | |
| *Lota lota* (L.) | — | — | — | — | — | — | + | — | — | — | — | — | — | — | — | — |
| Family ***Periophthalmidae*** | | | | | | | | | | | | | | | | |
| *Periophthalmus cantonensis* (OSBECK) | — | — | — | — | — | — | — | + | + | + | + | + | + | — | — | — |
| Family ***Hemirhamphidae*** | | | | | | | | | | | | | | | | |
| *Hyporhamphus sajori* (T. & S.) | — | — | — | — | — | — | + | + | + | + | + | + | — | + | — | — |

+ . . . . Upper reaches. ° . . . . Endemic species.

The above list, if statistically explained, will amount to 29 families, 85 genera, and 150 species, among which true freshwater fishes count 104 species, anadromous, catadromous, and brackish-water fishes 46, and endemic species 43.

Judging from table II, the freshwater fishes in Chosen comprise 72 species of *Cyprinidae*, nearly half of its freshwater

**Table II**

**List of the families of freshwater fishes in Chosen**

| Families | True fresh-water fishes | Anadromous, catadromous, and brackish water fishes | Total | Endemic species | Number of genera |
|---|---|---|---|---|---|
| Petromyzontidae | 2 | 1 | 3 | — | 1 |
| Acipenseridae | — | 2 | 2 | — | 1 |
| Engraulidae | — | 2 | 2 | — | 1 |
| Salmonidae | 1 | 4 | 5 | 1 | 3 |
| Coregonidae | 3 | — | 3 | 1 | 1 |
| Thymallidae | 1 | — | 1 | 1 | 1 |
| Plecoglossidae | — | 1 | 1 | — | 1 |
| Osmeridae | — | 5 | 5 | 2 | 3 |
| Salangidae | — | 4 | 4 | — | 4 |
| Siluridae | 2 | — | 2 | 1 | 1 |
| Bagridae | 9 | — | 9 | 4 | 5 |
| Cyprinidae | | | | | |
| Cyprininae | 2 | — | 2 | — | 2 |
| Gobioninae | 20 | — | 20 | 8 | 12 |
| Leuciscinae | 14 | 2 | 16 | 4 | 8 |
| Abramidinae | 6 | — | 6 | 1 | 3 |
| Acheilognathinae | 13 | — | 13 | 7 | 5 |
| Gobiobotinae | 7 | — | 7 | 6 | 3 |
| Cobitinæ | 8 | — | 8 | 2 | 4 |
| Flutidae | 1 | — | 1 | — | 1 |
| Anguillidae | — | 2 | 2 | — | 1 |
| Cyprinodontidae | 1 | — | 1 | — | 1 |
| Gasterosteidae | — | 4 | 4 | — | 2 |
| Osphromenidae | 1 | — | 1 | — | 1 |
| Ophicephalidae | 1 | — | 1 | — | 1 |
| Mugilidae | — | 3 | 3 | — | 2 |
| Oligoridae | — | 1 | 1 | — | 1 |
| Epinephelidae | 4 | — | 4 | 2 | 2 |
| Tetraodontidae | — | 1 | 1 | — | 1 |
| Cottidae | 4 | 2 | 6 | 2 | 3 |
| Platycephalidae | — | 1 | 1 | — | 1 |
| Eleotridae | 3 | — | 3 | — | 2 |
| Gobiidae | — | 9 | 9 | 1 | 4 |
| Gadidae | 1 | — | 1 | — | 1 |
| Periophthalmidae | — | 1 | 1 | — | 1 |
| Hemirhamphidae | — | 1 | 1 | — | 1 |
| | 104 | 46 | 150 | 43 | 85 |

fish-fauna. Besides this fact, the presence of *Acipenseridae* and *Salmonidae,* and the absence of Osseous *Ganoidei* makes it clear that Chosen belongs to what Günther terms the Palaearctic Region.

Moreover, as is clear from the list of distribution, in North Kankyodo and South Kankyodo (districts with rivers flowing into the Japan Sea and the upper reaches of the Yalu) such families of northern forms as *Petromyzontidae, Salmonidae, Coregonidae, Thymallidae, Gadidae, Cottidae, Gasterosteidae,* etc. are produced in abundance, while the species belonging to *Siluridae* and *Cyprinidae* of southern and Chinese forms are rare, and such families of southern forms as *Bagridae, Flutidae, Osphromenidae, Ophicephalidae,* etc. do not occur at all. Its fishfauna is therefore quite the same as that of the Siberian Subregion.

In the next place, in the greater part of Chosen, excepting North and South Kankyodo, such families of fishes that live in warm waters, as *Siluridae, Bagridae, Flutidae, Osphromenidae, Ophicephalidae, Cyprinodontidae,* etc. are found abundantly, and species belonging to Cyprinidae are exceedingly numerous. On the contrary, families of northern forms, such as *Petromyzontidae, Salmonidae, Coregonidae,* and *Cottidae* are seldom found, and, if found at all, are limited to the upper reaches of the rivers. In particular, fishes belonging to *Thymallidae* and *Gadidae* do not live here at all. From this state of distribution, it is undoubtedly allied to the Chinese Subregion.

It appears to me, from the above facts, that Chosen can be divided into two parts: (1) a part belonging to the Siberian Subregion and (2) the other belonging to the Chinese Subregion, both being a section of the Palaearctic Region.

### *(1) Siberian Subregion*

This Siberian Subregion to which North and South Kankyodo belong, can again be divided into two districts: (a) a district with rivers flowing into the Japan Sea and (b) a district forming the upper reaches of the Yalu.

#### (a) The part of Kankyodo with rivers flowing into the Japan Sea (the Maritime District)

There are no scholastics researches concerning this part of

Chosen except some papers on the Tumen River by L. S. BERG (1914), and by T. MORI (1930). As to the other rivers, no investigations whatever have been made. The result of my personal investigation has enabled me not only to identify all the fishes of these rivers, but also to systematize my collection into the following chart of distribution showing the relations of the fishes with neighbouring countries.

**Table III**

**Distributional list of freshwater fishes in Chosen to show the relations with the neighbouring countries.**

| Specific names | Greater part of Chosen | Japan Proper | Amur | Maritime District | Siberia | Hokkaido | Karafuto | North China | Middle China |
|---|---|---|---|---|---|---|---|---|---|
| *Lampetra japonica* | + | + | + | + | + | + | + | − | − |
| *L. reissneri* | + | + | + | + | + | + | + | − | − |
| *Acipenser mikadoi* | − | + | − | + | + | + | + | − | − |
| *Oncorhynchus masou* | + | + | + | + | + | + | + | − | − |
| *O. keta* | + | + | + | + | + | + | + | − | − |
| *O. gorbuscha* | − | − | + | + | + | + | + | − | − |
| *Salverinus malma* | − | + | + | + | + | + | + | − | − |
| '*Brachymystax tumensis* | − | − | − | − | − | − | − | − | − |
| *Plecoglossus altivelis* | + | + | − | − | − | + | − | + | − |
| *Osmerus dentex* | − | + | + | + | + | + | + | − | − |
| '*Spirinchus verecundus* | − | − | − | − | − | − | − | − | − |
| *Hypomesus olidus* | − | + | + | + | + | + | + | − | − |
| *H. japonicus* | − | + | − | − | − | + | − | − | − |
| '*Mallotus elongatus* | − | − | − | − | − | − | − | − | − |
| *Salangichthys microdon* | + | + | − | + | − | + | + | − | + |
| *Cyprinus carpio* | + | + | + | + | − | + | − | + | + |
| *Carassius auratus* | + | + | + | + | + | + | + | + | + |
| *Pseudorasbora parva* | + | + | + | + | − | − | − | + | + |
| *Gobio gobio* | − | − | + | + | + | − | − | + | − |
| *Leuciscus waleckii* | − | − | + | + | − | − | + | + | − |
| *L. brandti* | + | + | + | + | − | − | + | − | − |
| *L. hakonensis* | + | + | − | + | − | + | + | − | − |
| '*Phoxinus semotilus* | − | − | − | − | − | − | − | − | − |
| *Ph. lagowskii* | + | − | + | + | − | − | − | + | − |
| *Ph. oxycephalus* | + | − | + | + | − | − | − | + | + |
| *Ph. oxyrhynchus* | − | − | − | − | − | − | − | − | − |
| *Ph. percnurus sachalinensis* | − | − | − | + | − | − | + | − | − |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Ph. phoxinus* | − | − | + | + | + | − | − | − | − |
| *Rhodeus sericeus* | − | − | + | + | − | − | + | − | − |
| *Cobitis taenia* | + | + | + | + | + | − | + | + | + |
| *Misgurnus anguillicaudatus* | + | + | + | + | − | + | − | + | + |
| *Lefua costata* | + | − | + | + | − | − | − | + | − |
| *Barbatula toni* | + | − | + | + | + | + | + | + | − |
| *B. intermedia* | − | − | − | + | + | − | − | − | − |
| *Parasilurus asotus* | + | + | + | + | − | − | − | + | + |
| *Gasterosteus aculeatus* | + | + | + | + | + | + | + | − | − |
| *Pungitius sinensis* | − | + | + | + | − | + | − | + | + |
| *P. brevispinosus* | − | − | − | + | − | + | − | − | − |
| *P. tymensis* | − | − | − | + | − | + | + | − | − |
| *Mugil cephalus* | + | + | − | + | − | − | − | + | + |
| *Lateolabrax japonicus* | + | + | + | + | − | − | − | + | + |
| *Cottus poecilopus* | + | − | + | + | + | − | − | − | − |
| *C. czerskii* | − | − | − | + | − | − | − | − | − |
| °*C. hangiongensis* | − | − | − | − | − | − | − | − | − |
| *Myoxocephalus jaok* | − | − | + | + | − | − | + | − | − |
| *Trachydermus fasciatus* | + | + | − | − | − | − | − | + | + |
| *Percottus glehni* | − | − | + | + | − | − | − | + | − |
| *Chaenogobius macrognathus* | + | + | + | + | − | + | + | − | − |
| *Rhinogobius similis* | + | + | + | + | − | + | − | + | − |
| *Rh. giurinus* | + | + | + | + | − | − | − | + | + |
| *Tridentiger obscurus* | + | + | − | + | − | + | − | − | − |
| *T. bifasciatus* | + | + | + | + | − | − | − | + | + |
| *Acanthogobius flavimanus* | + | + | − | + | − | + | − | − | − |
| | 29 | 30 | 33 | 44 | 16 | 25 | 23 | 21 | 14 |

It may be seen from the above, that, of the 54 species occuring in this part, excepting 6 endemic species, 48 have relations with neighbouring countries. Now, of these 48 species, 44 are in common with the Maritime District, which occupies 92%. The species which are in common with the Amur District are 33, i.e. 70%. Karafuto has 23 common species, Hokkaido 25. Karafuto and Hokkaido seem to have few in common, compared with 30 of Japan Proper and 29 of the greater part of Chosen, as in the former two districts the number of species of fishes is small: 31 in Karafuto and 35 in Hokkaido; in fact about 70% of their fishes are common to both. On the contrary, though Japan Proper has about 100 species of freshwater fishes, and the greater part of Chosen, 125 species, the former has only 30% and the later, 24% in common,

after all. On the other hand, close examination of its endemic species shows that they are of the northern type.

Since this part produces fishes of almost the same species as those in the Maritime Province, it is easily proved that it belongs to the Maritime District, as presupposed by Professor T. KAWAMURA, and has a close relation with Karafuto and Hokkaido.

That this part has nearly the same fish-fauna as that of the Maritime Province is accounted for by the fact that this part is washed, like the Maritime Province, by a cold current called the Liman Current, and on that account in both there are the same species belonging to *Salmonidae, Osmeridae, Gasterosteidae, Acipenseridae, Petromyzontidae, Cottidae, Salangidae,* etc., which are related to cold currents.

**(b) Upper reaches of the Yalu or the Oryoku River (Amur District)**

As it was stated in my paper: "On the freshwater fishes from the Yalu River" (1927), the fish-fauna of the upper reaches of the Yalu River Very closely resembles that of the Amur. I give, at the end of this pamphlet, a chart of distribution, in which it may be seen how they resemble each other.

As may be seen from table IV, of the 20 species produced in this part, there are two species endemic to the upper reaches of the Yalu; and of the remaining 18 species, there are 15 species in common with the Amur, that is, 83%. There are 12 species in common with the greater part of Chosen, that is, 67%. It is a matter worthy of notice that, in spite of the river being the same, the upper reaches resembles the Amur in fish-fauna far more than the middle and lower reaches, and besides this, the endemic species of this part are of the Amur system, having close relations with those produced in the Amur.

These facts have induced me to conclude that this part should be referred to the Amur District.

This district, on the other hand, is a part of the Kaima Plateau, with an altitude of 1.000 meters. Though there is a kinship to the Amur District in climatic conditions, there is a significant phenomenon that causes a decided difference in their fish-distribution. It seems that, in the remote past, this river was the upper stream

**Table IV**
**List of the freshwater fishes in the upper reaches of the Yalu River to show the close resemblance to those of the Amur.**

| Specific names | Greater part of Chosen | Amur | Maritime district | Siberia | Hokkaido | Karafuto | Japan Proper | North China | Middle China |
|---|---|---|---|---|---|---|---|---|---|
| *Lampetra morii* | + | − | − | − | − | − | − | + | − |
| *Salverinus malma curilus* | + | + | + | − | + | + | − | − | − |
| °*Hucho ishikawae* | − | − | − | − | − | − | − | − | − |
| *Brachymystax lenok* | + | + | + | + | − | − | − | − | − |
| *B. coregonoides* | − | + | − | + | − | − | − | − | − |
| °*Thymallus jaluensis* | − | − | − | − | − | − | − | − | − |
| *Leuciscus waleckii* | − | + | + | − | − | + | − | + | + |
| *Phoxinus oxycephalus* | + | + | + | − | − | − | − | + | + |
| *Phoxinus phoxinus* | − | + | + | + | − | − | − | − | − |
| *Opsariichthys bidens* | + | + | − | − | − | − | − | + | + |
| *Gobio gobio* | − | + | + | + | − | − | − | + | − |
| *Sarcocheilichthys soldatovi* | − | + | − | − | − | − | − | − | − |
| *Ladislavia taczanowskii* | + | + | − | − | − | − | − | − | − |
| *Cobitis taenia* | + | + | + | + | − | + | + | + | + |
| *Barbatula toni* | + | + | + | + | + | + | − | + | − |
| *Parasilurus asotus* | + | + | + | − | − | − | + | + | + |
| *Siniperca scherzeri* | + | − | − | − | − | − | − | + | + |
| *Cottus poecilopus* | + | + | + | + | − | − | − | − | − |
| *Anguilla japonica* | + | − | − | − | + | − | + | + | + |
| *Lota lota* | − | + | − | + | − | + | − | − | − |
| | 12 | 15 | 10 | 8 | 3 | 5 | 3 | 10 | 7 |

of the Sungari River, which, owing to some convulsion of nature, was shut off in the middles; the stream, thus intercepted, running through the Chosen backbone mountain range and flowing west, came to join the Yalu, in a secondary process of water erosion. This is a mere hypothesis, but unless it is accepted, there is no accounting for the difference in distribution. This theory of mine is in perfect agreement with a geological article by Dr. S. NAKAMURA, Professor of Geology, Kyoto Imperial University published two years after my theory was published. (See "Nihon Chiri Fuzoku Teikei"-Chosen no Bu Jô, or "Exhaustive Collection of Information concerning the Geography aud Customs of Japan":

the Volumes of Chosen(1929), part 1, p. 50).

Moreover, this district differs in the point of fish-fauna from the districts of North and South Kankyodo that have rivers flowing into the Japan Sea, in the following way:—

(1) Of *Salmonidae*, there is no genus belonging to *Oncorhynchus*, while there is a great abundance of fishes of the two genera, *Hucho* and *Salverinus*.

(2) *Gadidae* and *Thymallidae* are produced in the former, while they are not in the latter.

(3) In this district *Anguillidae* and *Epinepheridae* make their intrusion.

(4) Of *Cyprinidae*, such genera as *Ladislavia*, *Sarcocheilichthys*, and *Opsariichthys*, which are not found in the latter district, are found here.

**(2) *Chinese Subregion***

**(c) Greater part of Chosen (Chosen District)**

In the rest of Chosen, that is, Chosen minus the above districts, the fish-fauna is very abundant, its species amounting to 125, the chart of distribution of which is as follows:—

**Table V**

**List of the distribution of the freshwater fishes in the greater part of Chosen to show the relations with those of adjacent territories.**

| Specific names | Japan Proper | North China | Middle China | Amur | Maritime District | Siberia | Hokkaido | Karafuto |
|---|---|---|---|---|---|---|---|---|
| *Lampetra japonica* | + | − | − | + | + | + | + | + |
| *L. reissneri* | + | − | − | + | + | + | + | − |
| *L. morii* | − | + | − | − | − | − | − | − |
| *Acipenser sinensis* | − | + | + | − | − | − | − | − |
| *Oncorhynchus masou* | + | − | − | + | + | + | + | + |
| *O. keta* | + | − | − | + | + | + | + | + |
| *Salverinus malma curilus* | − | − | − | − | + | + | + | + |
| *Brachymystax lenok* | − | − | − | + | + | + | − | − |
| *Plecoglossus altivelis* | + | + | − | − | − | − | + | − |
| *Salanx ariakensis* | + | + | − | − | − | − | − | − |
| *Protosalanx hyalocranius* | − | + | − | − | − | − | − | − |
| *Neosalanx andersoni* | − | + | − | − | − | − | − | − |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Coilia nasus* | + | + | + | − | − | − | − | − |
| *C. ectenes* | − | + | + | − | − | − | − | − |
| *Parasilurus asotus* | + | + | + | + | + | − | − | − |
| °*P. microdorsalis* | − | − | − | − | − | − | − | − |
| *Pelteobagrus fulvidraco* | − | + | + | + | − | − | − | − |
| *Pseudobagrus vacheli* | − | + | + | − | − | − | − | − |
| °*P. emarginatus* | − | − | − | − | − | − | − | − |
| °*P. brevicorpus* | − | − | − | − | − | − | − | − |
| *Leiocassis dumerili* | − | + | + | − | − | − | − | − |
| *L. brashnikowi* | − | − | − | + | − | − | − | − |
| *L. ussuriensis* | − | + | − | + | − | − | − | − |
| °*Liobagrus andersoni* | − | − | − | − | − | − | − | − |
| °*L. mediadiposalis* | − | − | − | − | − | − | − | − |
| *Cyprinus carpio* | + | + | + | + | + | − | + | − |
| *Carassius auratus* | + | + | + | + | + | + | + | + |
| *Hemibarbus labeo* | − | + | + | + | − | − | − | − |
| *H. longirostris* | − | + | − | − | − | − | − | − |
| °*Belligobio mylodon* | − | − | − | − | − | − | − | − |
| *Pseudogobio esocinus* | + | + | − | − | − | − | − | − |
| *Abbottina rivularis* | − | + | + | + | − | − | − | − |
| *Leucogobio strigatus* | − | + | − | + | − | − | − | − |
| °*L. coreanus* | − | − | − | − | − | − | − | − |
| °*L. majimae* | − | − | − | − | − | − | − | − |
| *Pseudorasbora parva* | + | + | + | + | + | − | − | − |
| *Ladislavia taczanowskii* | − | − | − | + | − | − | − | − |
| °*Sarcocheilichthys morii* | − | − | − | − | − | − | − | − |
| °*S. kobayashii* | − | − | − | − | − | − | − | − |
| °*S. wakiyae* | − | − | − | − | − | − | − | − |
| *S. soldatovi* | − | − | − | − | − | − | − | − |
| *S. lacustris* | − | − | − | + | − | − | − | − |
| *Coreius cetopsis* | − | + | + | + | − | − | − | − |
| °*Pungtungia herzi* | − | − | − | − | − | − | − | − |
| *P. hilgendorfi* | + | − | − | − | − | − | − | − |
| °*Pseudopungtungia nigra* | − | − | − | − | − | − | − | − |
| *Aphyocypris chinensis* | − | + | + | − | − | − | − | − |
| *Leuciscus brandti* | + | − | − | + | + | − | − | + |
| *L. hakonensis* | + | − | − | − | + | − | + | + |
| °*Phoxinus semotilus* | − | − | − | − | − | − | − | − |
| *Ph. oxycephalus* | − | + | + | + | + | − | − | − |
| °*Coreoleuciscus splendidus* | − | − | − | − | − | − | − | − |
| *Opsariichthys bidens* | − | + | + | + | − | − | − | − |
| *Zacco platypus* | + | + | + | − | − | − | − | − |
| *Z. temmincki* | + | − | − | − | − | − | − | − |
| *Squaliobarbus curriculus* | − | + | + | + | − | − | − | − |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| °*Ochetobius lucens* | − | + | − | − | − | − | − | − |
| °*Parapelecus jouyi* | − | − | − | − | − | − | − | − |
| *P. eigenmanni* | − | + | − | + | − | − | − | − |
| *Culter erythropterus* | − | + | + | + | − | − | − | − |
| *C. recurviceps* | − | + | + | − | − | − | − | − |
| *C. brevicauda* | − | + | + | + | − | − | − | − |
| *Hemiculter leucisculus* | − | + | + | + | − | − | − | − |
| *Acheilognathus lanceolata* | + | − | − | − | − | − | − | − |
| °*A. yamatsutae* | − | − | − | − | − | − | − | − |
| *Acanthorhodeus asmussi* | − | + | − | + | − | − | − | − |
| °*A. gracilis* | − | − | − | − | − | − | − | − |
| °*Paracheilognathus coreanus* | − | − | − | − | − | − | − | − |
| °*P. pseudorhombea* | − | − | − | − | − | − | − | − |
| *P. tabira* | + | − | − | − | − | − | − | − |
| *Rhodeus ocellatus* | + | + | + | − | − | − | − | − |
| °*Rh. uyekii* | − | − | − | − | − | − | − | − |
| °*Rh. suigensis* | − | − | − | − | − | − | − | − |
| *Rh. notatus* | − | + | − | − | − | − | − | − |
| °*Pseudoperilampus hondae* | − | − | − | − | − | − | − | − |
| *Saurogobio dabryi* | − | + | + | + | − | − | − | − |
| °*Gobiobotia macrocephalus* | − | − | − | − | − | − | − | − |
| °*G. brevibarba* | − | − | − | − | − | − | − | − |
| °*G. naktongensis* | − | − | − | − | − | − | − | − |
| °*Microphysogobio koreensis* | − | − | − | − | − | − | − | − |
| °*M. longidorsalis* | − | − | − | − | − | − | − | − |
| °*M. yaluensis* | − | − | − | − | − | − | − | − |
| *Cobitis taenia* | + | + | + | + | + | + | − | + |
| °*C. multifasciatus* | − | − | − | − | − | − | − | − |
| °*C. rotundicauda* | − | − | − | − | − | − | − | − |
| *Misgurnus anguillicaudatus* | + | + | + | + | + | − | + | − |
| *M. mizolepis* | − | + | + | − | − | − | − | − |
| *Lefua costata* | − | + | − | + | + | − | − | − |
| *Barbatula toni* | − | + | − | + | + | + | + | + |
| *Fluta alba* | + | + | + | − | − | − | − | − |
| *Auguilla japonica* | + | + | + | − | − | − | + | − |
| *A. mauritiana* | + | − | − | − | − | − | − | − |
| *Aplocheilus latipes* | + | + | + | − | − | − | − | − |
| *Gasterosteus aculeatus* | + | − | − | + | + | + | + | + |
| *Macropodus chinensis* | + | + | + | − | − | − | − | − |
| *Ophicephalus argus* | − | + | + | + | − | − | − | − |
| *Mugil cephalus* | + | + | + | − | + | − | − | − |
| *M. oeur* | + | + | + | − | − | − | − | − |
| *Liza haematochila* | + | + | + | − | − | − | − | − |
| *Lateolabrax japonicus* | + | + | + | + | + | − | − | − |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| °*Coreoperca herzi* | − | − | − | − | − | − | − | − |
| *C. kawamebari* | + | − | − | − | − | − | − | − |
| °*Siniperca aequiformis* | − | − | − | − | − | − | − | − |
| *S. scherzeri* | − | + | + | − | − | − | − | − |
| *Spheroides ocellatus* | + | + | + | − | − | − | − | − |
| *Cottus poecilopus* | − | − | − | + | + | + | − | − |
| °*C. shiragiensis* | − | − | − | − | − | − | − | − |
| *Trachydermus fasciatus* | + | + | + | − | − | − | − | − |
| *Platycephalus indicus* | + | + | + | − | − | − | − | − |
| *Odontobutis obscurus* | + | + | + | − | − | − | − | − |
| *Eleotris potamophila* | − | + | + | − | − | − | − | − |
| *Chaenogobius macrognathus* | + | − | − | − | + | − | + | + |
| *Rhinogobius similis* | + | + | − | + | + | − | + | − |
| *Rh. giurinus* | + | + | + | − | + | − | − | − |
| *Tridentiger obscurus* | + | − | − | − | + | − | + | − |
| *T. birasciatus* | + | + | + | − | + | − | − | − |
| °*T. coreanus* | − | − | − | − | − | − | − | − |
| *Acanthogobius flavimanus* | + | + | − | − | + | − | + | − |
| *A. ommaturus* | − | + | + | − | − | − | − | − |
| *A. hasta* | + | + | + | − | − | − | − | − |
| *Periophthalmus cantonensis* | + | + | + | − | − | − | − | − |
| *Hyporhamphus sajori* | + | + | + | − | − | − | − | − |
| | 46 | 65 | 49 | 37 | 27 | 11 | 17 | 11 |

As may be seen from this list, in the greater of Chosen such fishes of the families belonging to southern forms as *Bagridae*, *Flutidae, Anguillidae, Epinepheridae, Ophicephalidae, Osphromenidae, Cyprinodontidae,* etc. are produced in great quantities, and *Thymallidae* and *Gadidae,* of northern forms, do not exist. Likewise, such families as *Petromyzontidae, Salmonidae, Coregonidae, Cottidae,* etc. are rarely found, and, if found at all, in the upper reaches of rivers as remnants, excepting the eastern coastal districts. Especially *Gasterosteidae* and *Oncorhynchus* of *Salmonidae* do not seem to live anywhere except in the eastern coastal districts

Though L. S. Berg puts all the eastern coasts of Chosen, that is, as far south as Fusan, into his Maritime District. There occur along the eastern coast south of Gensan, such families of southern forms as *Bagridae, Ophicephalidae, Anguillidae, Cyprinodontidae,* and the following species of *Cyprinidae* which are not produced in the Maritime District, such as *Zacco temmincki, Zacco platypus, Coreo-*

*leuciscus splendidus, Pseudogobio esocinus,* etc., which have relations with Japan Proper and China. As for northern forms, only *Lampetra japonica, L. reissneri, Oncorhynchus masou, O. keta, Gasterosteus aculeatus, Barbatula toni,* and *Cottus hangiongensis* are found, while fishes of purely northern type such as *Oncorhynchus gorbuscha, Salverinus malma, S. malma curilus, Brachymystax tumensis, Pungitius sinensis, Cottus poecilopus, Rhodeus seriseus, Gobio gobio, Phoxinus phoxinus,* and species belonging to *Osmeridae,* do not exist at all. From these facts I put the eastern coast of Chosen south of Gensan into the greater part of Chosen.

Moreover, L. S. BERG puts the greater part of Chosen into the Amur Transitional Region; but I can not agree with this. Of the 125 species of fishes found in this district, we may leave out 36 endemic species. Of the remaining 89 species, those that are in common with North China are 73%; with Middle China, 55%; with Japan Proper, 52%; and with Amur, 40%. Thus its close relationship with North China is clearly seen. Take its endemic species on the other hand. The genera to which they belong are those of southern or Chinese forms, such as *Parasilurus, Pseudobagrus, Liobagrus, Belligobio, Leucogobio, Sarcocheilichthys, Pungtungia, Pseudopungtungia, Coreoleuciscus, Parapelecus, Acheilognathus, Acanthorhodeus, Rhodeus, Pseudoperilampus, Gobiobotia, Microphysogobio, Coreoperca, Siniperca,* etc., which have an affinity with China or Japan Proper. Of the genera to which these endemic species belong, *Belligobio* and *Pungtungia* are produced in Chosen and Japan Proper only; and four genera, *Coreoperca, Liobagrus, Pseudoperilampus,* and *Paracheilognathus* are distributed in Japan Proper and China, but not in the Amur. The endemic species that can be considered of northern forms are *Phoxinus semotilus* and *Cottus shiragiensis* only. These facts prove that the greater part of Chosen does not belong to the Amur Trasitional Region, but to the Chinese Subregion.

At the same time, though the fish-fauna of the greater part of Chosen resembles that of North China, the former has such endemic genera as *Coreoleuciscus* and *Pseudopungtungia;* and such genera as *Coreoperca, Belligobio, Pungtungia,* and *Liobagrus,* are not distributed in North China, while, on the contrary, in the

greater part of Chosen, *Parabramis, Xenocypris, Hypophthalmichthys, Elopichthys, Chanodichthys, Ctenopharyngodon, Leptobotia,* etc. do not make their intrusion. Thus there is a distinct difference in the fish-distribution.

And what arrests our special attention is that it has so many endemic species of its own, and unlike other districts that belong to the Chinese Subregion, such species of the Amur type as *Lampetra morii, Brachymystax lenok, Salverinus malma curilus, Ladislavia taczanowskii, Barbatula toni,* and *Cottus poecilopus* still remain in the upper reaches of the rivers north of the central part, in relic forms of those which abundantly existed when the temperature was low in olden times, thus forming a peculiar fish-fauna. Thus the greater part of Chosen, though belonging to the Chinese Subregion, makes up an independent district: the Chosen District.

This district is divided into the following four subdistricts by its physical features, topography, climate, ocean currents and tidal currents:—

(1) East Chosen Subdistrict—This is the general name for the part east of the backbone mountain range. The backbone inclining towards the east, and accordingly rivers in this subdistrict being small and short, the fish-fauna is poor and scanty; the number of species belonging to *Cyprinidae* is small, and though, as above stated, fishes of southern forms live in abundance, under the influence of cold oceanic currents are produced such northern type as *Lampetra, Oncorhynchus,* and *Gasterosteus,* and in river-mouth, *Gobiidae,* of northern forms.

(2) South Chosen Subdistrict—This is the name given to that part which contains rivers flowing southward in the south of the Shohaku Mountain Range and the Rorei Mountain Range. In this subdistrict, elements of Japan Proper such as *Coreoperca kawamebari* and *Pungtungia hilgendorfi* make their intrusion, and in this subdistrict only; and genera of Chinese or southern forms, such as *Squaliobarbus, Parapelecus, Saurogobio,* and *Leiocassis,* though they exist in West Chosen Subdistrict, do not intrude here; thus forming a fish-fauna somewhat different from the other subdistricts. Moreover there are some slight differences inside the subdistrict: the Rakuto River, under the influence of a cold current,

produces *Oncorhynchus*, *Lampetra*, and *Gasterosteus*, but in no other rivers belonging to this subdistrict.

(3) Central Chosen Subdistrict—West of the backbone range, the country is spacious and the rivers are long and broad. The rivers, north of the Kan River, show a difference of distribution according to the position: the upper reaches, or the middle and lower reaches. In the upper reaches, many fishes of southern forms live, but at the same time, on account of the altitude and cold climate, the six genera of northern forms, *Lampetra*, *Salverinus* (this genus lives north of the upper reaches of the Daidō River), *Brachymystax*, *Ladislavia*, *Barbatula*, and *Cottus*, are found as a few remnants. In this subdistrict, too, as fishes of mountainous rivulets, there are endemic species belonging to *Gobiobotia*, *Microphysogobio*, and *Coreoleuciscus*:—an altogether peculiar fish-fauna.

(4) West Chosen Subdistrict (including all the rivers south of the Kin river).—This subdistrict is of low and plain country, and the water temperature is comparatively high, so fishes of the upper reaches do not live there, but genera of southern forms, such as *Leiocassis*, *Pelteobagrus*, *Pseudobagrus*, *Liobagrus*, *Parasilurus*, *Fluta*, *Anguilla*, *Aplocheilus*, *Ophicephalus*, and *Macropodus*, and also *Cyprinidae* of Chinese forms, are produced in abundance; in the Yellow Sea, as an effect of the large difference between high and low tides such families of brackishwater fishes as mentioned below, come up, with the high tide, as far as the middle reaches: *Engraulidae*, *Salangidae*, *Mugilidae*, *Oligoridae*, *Tetraodontidae*, *Platycephalidae*, *Gobiidae*, *Periophthalmidae*, and *Hemirhamphidae*, thus forming a peculiar fish-fauna.

## IV Conclusion

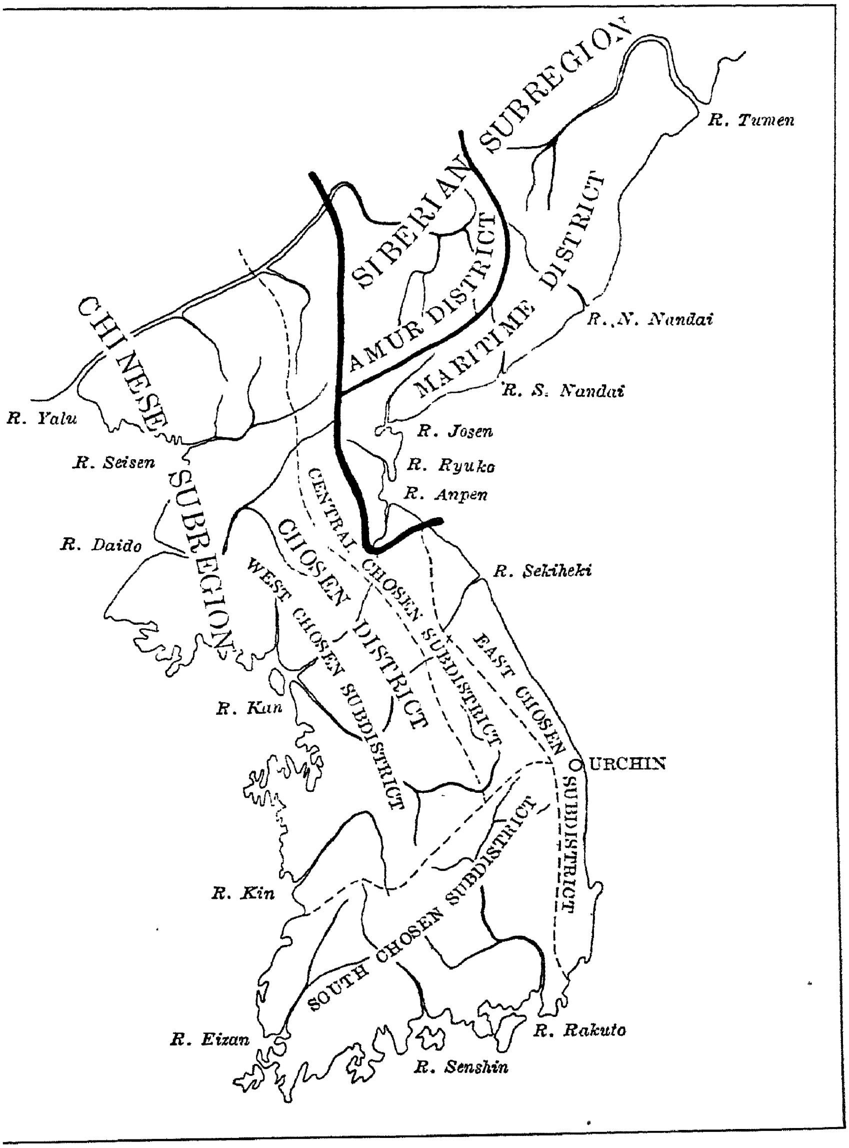
I will now sum up the above statements.

(1) Chosen belongs to the Palaearctic Region.

(2) Of Chosen, North Kankyodo and South Kankyodo belong to the Siberian Subregion, and the rest of Chosen, to the Chinese Subregion.

(3) That part which belongs to the Siberian Subregion, is divided into two parts:

a The Maritime District, or the district that has rivers




Distribution Map of Fishwater Fishes of Chosen

flowing into the Japan Sea.

b The Amur District, or the upper reaches of the Yalu River or the Oryoku River.

(4) That part which belongs to the Chinese Subregion has umerous endemic species, and forms the Chosen District.

(5) The Chosen District again is divided into four subistricts

a East Chosen

b South Chosen

c Central Chosen, or the upper reaches of rivers flowing into the Yellow Sea.

d West Chosen, or the lower reaches of the foregoing.

(6) The greater part of Chosen is the country where the Siberian Subregion and the Chinese Subregion border each other; their point of contact, the East Chosen Subdistrict receives the influence of the Maritime District, and the Central Chosen Subdistrict receives that of the Amur District, mixing some northern forms with southern forms. But the elements of the former are extremely few. Therefore these two subdistricts should be put under the Chosen District.

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To......................................................

*With the Author's compliments.*

# ON A SHARK TOOTH FROM THE LOWER EOCENE.

# ON FOSSIL FISH-REMAINS FROM THE KAREWAS OF KASHMIR.

# FOSSIL FISH-REMAINS FROM THE SALINE SERIES OF NORTH-WESTERN INDIA.

BY

**SUNDER LAL HORA, D.Sc., F.R.S.E., F.N.I.,**

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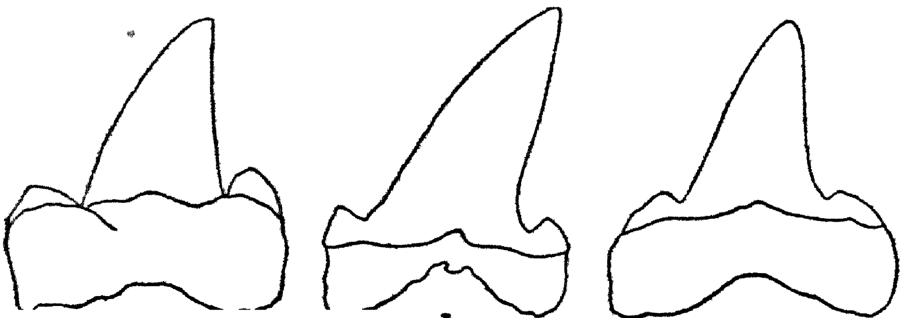
**(With Plates 14 and 15.)**

[ From the *Records of the Geological Survey of India*, Vol. 72, Pt. 2, pp. 174-194, (1937).]

# ON A SHARK TOOTH FROM THE LOWER EOCENE. BY SUNDER LAL HORA, D.Sc., F.R.S.E., F.N.I., *Assistant Superintendent, Zoological Survey of India, Calcutta.**

The shark tooth[1] reported here was sent to me by Mr. E. R. Gee of the Geological Survey of India who obtained it in 1931, from just south of the Salt Department Rest House at Sar Kalan, 3 miles E.S.E. of Nurpur in the Salt Range, Jhelum District, Punjab. It was found in "the flaggy, foraminiferal, pinkish-grey (weathering yellow-brown) limestone, which is associated with variegated sandstones below the Nummulitic coal shale horizon." Mr. Gee has informed me that, on stratigraphical grounds, the fossil should be referred to the Ranikot (Lower Eocene) age (Gee, 1935; Davies and Pinfold, 1937).



*a.* *b.* *c.*

Teeth of three species of *Lamna* Cuv. *a. Lamna appendiculata* Ag.; *b. Lamna* sp. from the Salt Range, Punjab, ×1½; *c. Lamna obliqua* Ag.

Figures *b.* and *c.* are copies from Zittel and all the three teeth are enlarged to the same length for the purpose of comparison.

The tooth (No. K39/514*a*) is of a burnt amber colour; it is very stout and consists of a large, conical cusp and of two well-defined, fairly broad, somewhat obtuse, lateral denticles, one at each side of the base of the cusp. The root, which was embedded in the rock and has been exposed by using acid to dissolve the rock, is large, expanded laterally and only slightly bifurcate. The surface of the tooth is well polished and ornamented with small pits; the central

*Published with permission of the Director, Zoological Survey of India.

[1] Besides one complete tooth, lateral denticles or portions of lateral denticles of several other teeth were found embedded in rock No. K39/514.

portion is somewhat raised so that the exposed surface (probably external) is somewhat convex. The lateral edges of the cusp are sharp and entire and the tip is pointed. The measurements of the tooth are:

| | |
|---|---|
| Length of cusp . . . . | 17 mm. |
| Width of base of cusp . . . | 10 mm. |
| Width of base including that of denticles | 15 mm. |

From the nature of the tooth it is clear that it should be referred to the family Lamnidae[1] in which the teeth are pointed and are usually of a large size; the lateral denticles may or may not be present. Of the genera of the Lamnidae, the teeth of the genus *Lamna* Cuvier possess a somewhat broader cusp; the lateral denticles are also larger. The fossil tooth should, therefore, belong to this genus. According to Zittel (1932, page 77), *Lamna* is

> "very abundant in the Chalk, Tertiaries, and existing seas. Teeth of *L. appendiculata* Ag. universally distributed in Upper Cretaceous. *L. obliqua* Ag. sp., large teeth from the Eocene. *L. gafsana* White. Eocene; Tunis."

So far as I am aware *Lamna* (*sensu stricto*) has not hitherto been recorded from the Indian seas.[2] The recent species, *L. nasus*, is, however, known "from the British Isles, the Mediterranean, the Western Atlantic, and from Japan" (Garman, 1913, p. 35). A species has recently been described from New Zealand (Phillips, 1935, p. 239). The discovery of a tooth of *Lamna* from the Salt Range is, therefore, of special interest.

The teeth of the present-day, widely distributed porbeagle shark —*L. nasus*—are provided "with broad two-rooted base and slender lanceolate cusp at the base of each side of which in the larger specimens there is a sharp denticle." (Garman, 1913.) The fossil tooth described here seems to represent an intermediate type between the more massive teeth of *L. appendiculata* and *L. obliqua* and the slender teeth of *L. nasus*.

[1] Garman in his monograph on "The Plagiostomia" (*Mem. Mus. Comp. Zool. Harvard College*, XXXVI, 1913) considers *Lamna* as a subgenus of *Isurus* Rafinesque and has, therefore, adopted the family name Isuridae. *Lamna* is, however, distinguished from *Isurus* by the fact that the teeth of the former are provided with denticles on either side of the base in adults, while in *Isurus* the teeth are without denticles.

[2] Attention may here be directed to the teeth of *Carcharias tricuspidatus* Day (= *Odontapsis taurus* Müll & Henle) which are "very large, awl-shaped, smooth except at the base, where there exists a small basal cusp on either side" (Day, *Fish. India*, p. 713, pl. clxxxvi, fig. 1, 1878). From Day's figures of the teeth it is clear that the fish should be referred to the genus *Odontapsis* Ag. The teeth of *Odontapsis* are similar to those of *Lamna*, but are much more slender and the basal denticles are very small and sharp.

In describing the Tertiary fishes of India, Lydekker (1886, p. 243) described two vertebrae under the family Lamnidae but he was unable to assign them to any genus. He observed:

"The vertebra of a shark represented in plate XXXVII, figs. 9, 9a, is one of two similar specimens in the Indian Museum from the Siwaliks of Perim Island. They agree very closely with the vertebræ of *Lamna cornubica*, and not improbably belong either to *Lamna* or *Carcharias*."

Both the fossil tooth described above and the vertebra figured by Lydekker show that fishes similar to *Lamna nasus* flourished in the Tertiary seas and estuaries of India.

As regards the specific identity of the fossil tooth it is very difficult to come to any definite conclusion, as Weiler's (1931, 1932, 1933) and Murray's (1930) recent papers, in which species of *Lamna* are figured, are not available in Calcutta. I have, however, consulted White's (1931, 1934) papers and find that the tooth under report does not agree with any of the species of which the teeth are figured by him.

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# ON FOSSIL FISH-REMAINS FROM THE KAREWAS OF KASHMIR. BY SUNDER LAL HORA, D.SC., F.R.S.E., F.N.I., *Assistant Superintendent, Zoological Survey of India, Calcutta.* (With Plate 14.)*

## I.—INTRODUCTION.

In 1932 and 1935, Dr. Hellmut de Terra, Leader of the Yale North India Expedition, collected a number of fossil fish-remains in the Kashmir valley which he sent to me for study and report. These remains, which are of a very fragmentary nature, are not in a good state of preservation. The earlier lot, which consisted of bits of spines and vertebrae, was almost indeterminable. The 1935 lot, however, comprised one greatly crushed skull (Specimen No. K40/247), impressions of the caudal region of two specimens and a counterpart of one of these, a piece of skin with scales and two pharyngeal teeth. From the nature of the scales it has been possible to refer the entire material to the sub-family *Schizothoracinae* (Family: Cyprinidae) which, as is clear from Mr. Mukerji's (1936) report on the fishes collected by the Yale North India Expedition, forms, even at the present day, the most dominant element in the fish fauna of the valley.

Most of the specimens reported upon were collected from Ningal Nullah, near Gulmarg, at an altitude of about 9,800 feet. Dr. de Terra in his letter dated April, 7, 1937 informs me that

> "The specimens collected in Ningal Nullah, near Gulmarg, come from an exposure of Lower Karewa beds at an altitude of 9,800 feet. The Lower Karewas, as was indicated in several publications of mine, should be referred to the first Interglacial. At this particular locality the laminated Karewa silts are tilted and unconformably overlain by Glacio-fluvial outwash deposits belonging to a retreat phase of the second Ningal glacier. These fish-bearing beds also yielded many fossil leaves representing a Pine-Oak-Willow flora. A petrologic analysis of the Lower Karewas has just been completed by Dr. Krynine of Yale University, who states that these beds were laid down in a lake, and that part of the sedimentary material suggests derivation from windblown silt."

* This article forms a continuation of the Biological Reports Nos. XVII and XVIII of the "Scientific Results of the Yale North India Expedition" (*Mem. Conn. Acad.*, X, pp. 299-359, 1936), and is published here with the permission of the Director, Zoological Survey of India.

According to Mr. D. N. Wadia of the Geological Survey of India the matrix of the fossil fishes consists of

> "A fine micaceous sandy clay such as occurs in thick beds in the Karewas of Kashmir. It may be a fluviatile or lacustrine deposit in still water; there is a faint trace of lamination showing intermittent deposition."

In the following account I propose to describe first the recognisable fragments and then to refer to their affinities. The ecological association of the fossil fish fauna is also discussed and it is pointed out that the occurrence of these fossils at an altitude of 9,800 feet affords additional evidence in favour of recent orogenic uplift movements in the Himalayas.

The whole of the material is deposited in the collection of the Geological Survey of India.

## II.—DESCRIPTION OF THE COLLECTION.

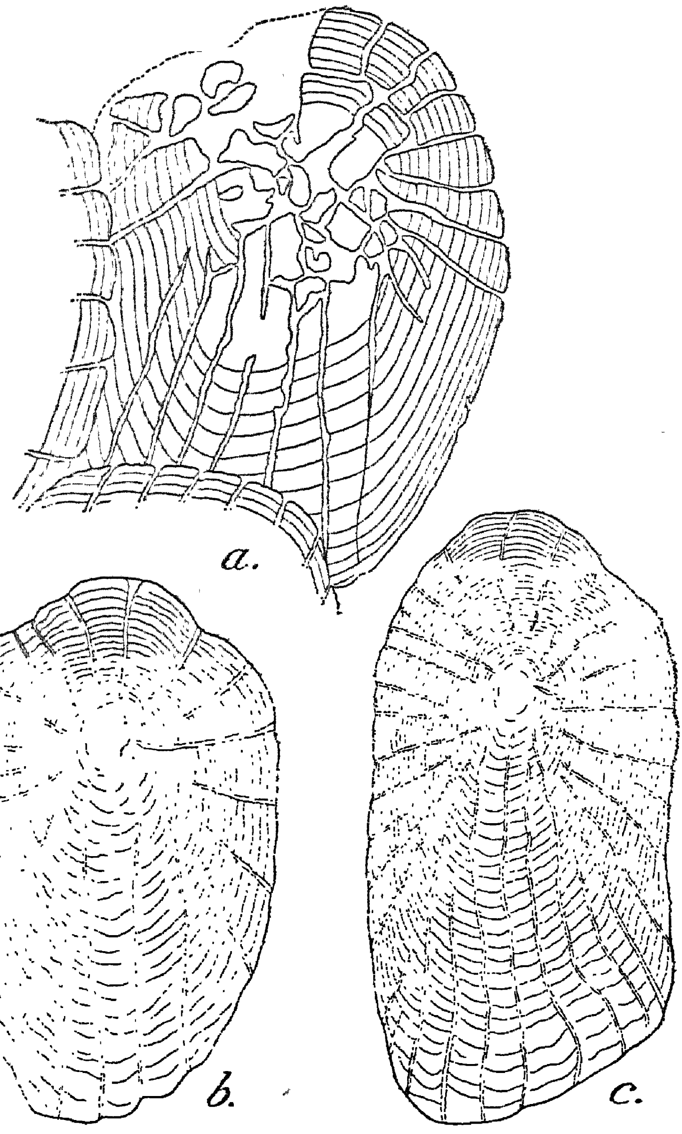
*Specimen No.* K40/241. A piece of skin immediately behind the head region and below the vertebral column preserved in lateral view.

*Locality.*—Ningal Nullah, near Gulmarg.

The bony elements are too fragmentary to be determined, but the skin is covered with small scales which slightly overlap one another (Plate XIV, fig. 1). All the scales show perfectly developed circuli and complete radii in all fields (Plate XIV, fig. 2). Each scale is somewhat oval in outline, with a number of radii arranged all over the surface; the apical radii, however, are much longer than others and are more widely spaced (Text-fig. 1*a*). The nucleus of the scales is basal and there are about 8-10 apical radii and an almost equal number of smaller lateral and basal radii.

The scales of the type described above are characteristic of the Schizothoracinae, (Chu, 1935), but there are slight differences in the case of different genera. The structure of the scales also varies according to the portion of the body from which they are examined. The genera that are known from the Kashmir valley are *Schizothorax* Heckel, *Oreinus* McClelland, *Schizopygopsis* Steindachner, *Diptychus* Steindachner and *Ptychobarbus* Steindachner. Of these *Schizopygopsis* possesses a more or less naked body, but the scales of other genera from above the pectoral fins were examined and it was found that the fossil scales described above show very close resemblance to those of *Schizothorax* (Text-fig. 1*b*) and *Oreinus*

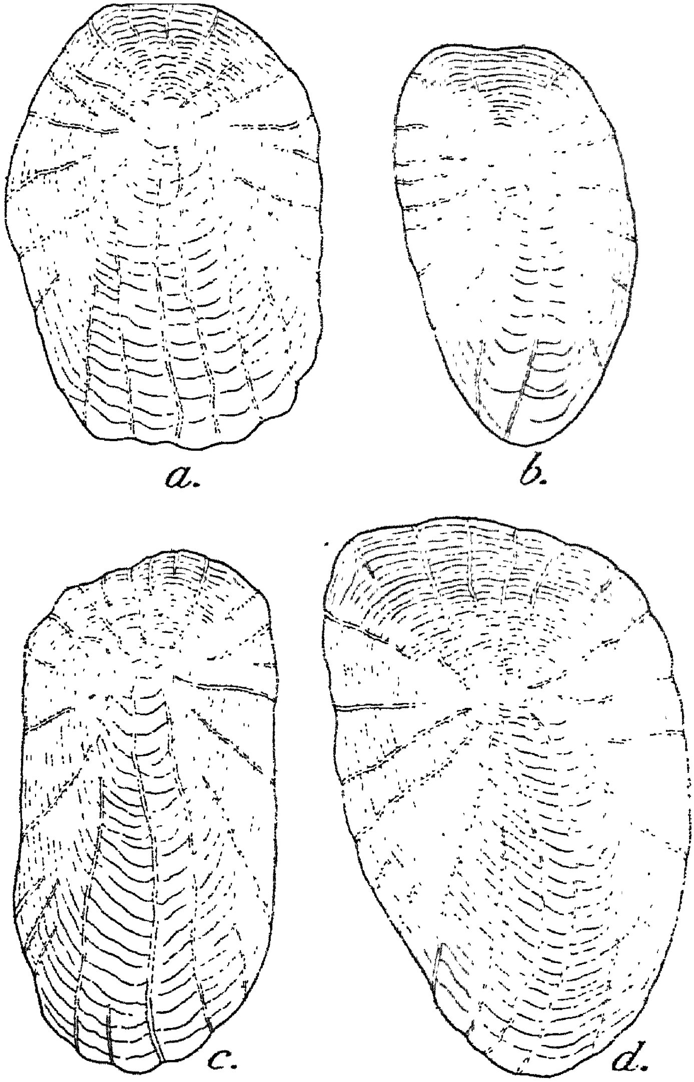
(Text-fig. 1*c*). The scales of a number of species of *Schizothorax* occurring in the Kashmir valley (Text-fig. 2) were examined, and it was found that the fossil scales are more closely allied to *Sch.*




TEXT-FIG. 1.—Fossil scales and scales of *Schizothorax* and *Oreinus* from above pectoral fin for comparison.

*a.* An incomplete fossil scale with portions of two neighbouring scales to show the nature of lepidosis and the structure of the scale. ×52; *b.* Scale of *Schizothorax esocinus* Heckel. ×38; *c.* Scale of *Oreinus sinuatus* (Heckel). ×38.

*curvifrons* (Text-fig. 2*a*) than to any other species of *Schizothorax* known from the Kashmir valley.



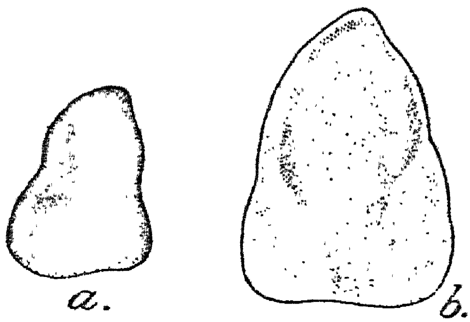

TEXT-FIG. 2.—Scales of certain Kashmir species of *Schizothorax*.

*a*. *Schizothorax curvifrons* Heckel. ×44; *b*. *Schizothorax micropogon* Heckel. ×44; *c*. *Schizothorax planifrons* Heckel. × 44; *d*. *Schizothorax longipinnis* Heckel. ×44.

*Specimen No.* K40/242. Underterminable pieces of bone and two pharyngeal teeth with their crowns exposed (Plate XIV, fig. 3).

*Locality*.—Ningal Nullah, near Gulmarg.

The two pharyngeal teeth are preserved in different positions (Plate XIV, fig. 4). The grinding surface of one is fully exposed while that of the other is inclined obliquely. The outline of the fully exposed tooth corresponds with the outline of the crown of a pharyngeal tooth of *Oreinus sinuatus* (Heckel) from Kashmir but the grinding surface of the fossil tooth is more worn out and plain (Text-fig. 3). Grinding pharyngeal teeth of the type represented by the fossil teeth are characteristic of the Schizothoracine genera, such as *Oreinus*, *Schizothorax*, etc. (*vide* Chue, 1935).



TEXT-FIG. 3.—Outline of the crown of a fossil pharyngeal tooth and that of *Oreinus sinuatus* (Heckel).

*a.* Fossil toth. ×22; *b.* Tooth of *Oreinus sinuatus* (Heckel). ×17.

*Specimens Nos.* K40/243 and K40/244. Three pieces of clay containing bones and impressions of the caudal region of a fish of the same type (Plate XIV, fig. 5).

*Locality.*—Ningal Nullah, near Gulmarg.

The anal fin is short, consisting of 5 branched rays and 2 undivided rays. The caudal fin is long and deeply forked. This region of the fossil fish agrees with the corresponding region of the Schizothoracine fishes, such as *Oreinus* (Plate XIV, fig. 6). The whole structure is of such a generalised nature that by itself it is not capable of specific determination.

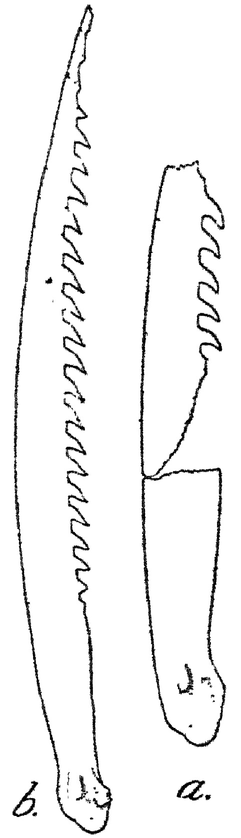
*Specimen No.* K40/245. Several loose, incomplete vertebrae of the opisthocoelus type.

*Locality.*—Several places in the Kashmir valley and Ladak.

Both caudal and trunk vertebrae are represented in this lot. They do not possess any special features which could be utilised in their determination. However, they resemble very closely the vertebrae of the Schizothoracinae.

Similar vertebrae were collected by Dr. de Terra from several localities.

*Specimen No.* K40/246. An incomplete dorsal spine in two pieces (Text-fig. 4).



TEXT-FIG. 4.—An incomplete, fossil, dorsal spine in two pieces, and a normal dorsal spine of *Oreinus sinuatus* (Heckel).

*a.* Fossil spine. × 3; *b.* Spine of *Oreinus sinuatus* (Heckel). × 3.

*Locality.*[1]—Unknown.

The basal portion of the spine is provided with an articular surface, while the distal portion is strongly denticulated along the inner border. The serrations are prominent and widely spaced.

[1] Dr. de Terra believes "that this and other localities referred to all come from the same Lower Karewa beds; mainly, the locality at Sombur on the right bank of the Jhelum, above Pampur".

Of the genera of the Schizothoracinae found in Kashmir, the dorsal spine is feeble in *Diptychus* and *Ptychobarbus*, while it is, strong and serrated in *Oreinus*, *Schizothorax* and *Schizopygopsis*. The last named genus is devoid of scales, so on *a priori* grounds the fossil spine may be referrable either to *Oreinus* or to *Schizothorax*.

The collection contains several other fragments of the nature of spines but it is very difficult to assign to them any definite systematic position.

## III.—AFFINITIES OF THE MATERIAL.

From the foregoing account of the various fragments of fossil fishes, it is clear that they should be referred to the genus *Oreinus* or *Schizothorax*. It has already been indicated (Hora, 1936) that the two genera are very closely related and are capable of interbreeding. In fact, all gradations of form between *Schizothorax* and *Oreinus* were found in a collection of recent fish from Chitral and it was concluded that the latter represents a fluviatile form of the former. In the collection of fish made by the Yale North India Expedition, Mukerji (1936) found a series of forms intermediate between *Schizothorax* and *Oreinus* and described two hybrid forms. At the present day both these genera are well represented in the lakes and larger streams of the Kashmir valley. It appears reasonable, therefore, to infer that the beds from which the fossil fish were obtained must have been laid down either at the bottom of a lake or a large sluggish river. This conclusion was also reached by Mr. D. N. Wadia from an examination of the matrix of the fossil fishes (*vide supra*, p. 179).

Both *Schizothorax* and *Oreinus* are comparatively low altitude genera and their occurrence at a height of 9,800 feet in the fossil state needs some explanation. To form some idea of the altitudinal distribution of the various Kashmir species of the *Schizothoracinae*, I give below a list of the present day fishes obtained by the Yale North India Expedition with the number of specimens of each and the altitudes, in feet, at which they were obtained.

1. *Schizothorax labiatus* (McClell) . . 1 specimen from 10,730 ft.
2. *Schizothorax longipinnis* Heckel . . 1 specimen from 5,196 ft.
3. *Schizothorax esocinus* Heckel . . . 10 specimens from 5,200 ft. and 2 specimens from 10,700 ft.
4. *Schizothorax planifrons* Heckel . . 9 specimens from 5,200 ft.
5. *Schizothorax micropogon* Heckel . . 10 specimens from 5,200 ft.
6. *Schizothorax curvifrons* Heckel . . 5 specimens from 5,200 ft.

| | |
|---|---|
| 7. *Oreinus sinuatus* (Heckel) . . . . | 5 specimens from 5,200 ft.; 5 specimens from 8,700 ft. and 3 specimens from 10,730 ft. |
| 8. Hybrids between *Schizothorax* × *Oreinus* . | 11 specimens from 5,200 ft. |
| 9. *Schizopygopsis stoliczkae* Steind. . . | 13 specimens from 10,730 to 14,203 ft. |
| 10. *Diptychus maculatus* Steind. . . . | 17 specimens from 10,250 to 15,215 ft. |
| 11. *Ptychobarbus conirostris* Steind. . . | 5 specimens from 8,790 to 13,521 ft. |

It is clear from the above that, as a general rule, *Schizothorax* and *Oreinus* are inhabitants of comparatively low altitudes, whereas *Schizopygopsis*, *Diptychus* and *Ptychobarbus* are only found at much higher altitudes. *Oreinus*, in particular, is a genus of the southern slopes of the Himalayas and is not found on the tableland of Central Asia. Though there are no definite observations on the migrations of *Schizothorax* and *Oreinus* to small torrential streams for breeding purposes, it seems probable that, like the trout, they may also ascend at times into the smaller streams of the higher reaches. The time during which the Yale North India Expedition collected fishes from the higher altitudes coincided with the breeding season of these fishes, *viz.*, June to September, and it is no wonder, therefore, that some specimens of *Oreinus* and *Schizothorax* were obtained by the Expedition at comparatively higher altitudes. The sizes of the specimens also indicate that more or less mature fishes were collected from the higher regions.

The fact that all the fossil fish remains obtained by Dr. de Terra are referrable to *Schizothorax* or *Oreinus* leads one to infer that the beds in which they are now found may have been laid down at an altitude of about 5,000 feet or lower and that their present position on the slopes of the Pir Panjal is due to recent orogenic uplift movements in the Himalaya (Sahni 1936*a*). This belief is further strengthened by the fact that the fossil scales probably belong to *Schizothorax curvifrons* Heckel, which, at the present day is indigenous to the valley of Kashmir and has not been found at an elevation higher than that of the valley. In an article on the Karewas of Kashmir, Sahni (1936) has stated:

"The fossil-bearing sediments near Gulmarg, like many other deposits of clay, sand and gravel on the NE slopes of the Pir Panjal, were no doubt laid down, as Dr. Stewart suggests, in the bed of a lake. *But that lake never existed at the high altitude where its bed is now seen.* Strange though it may seem, this lake must have

been situated several thousand feet lower, at the same level as the main valley of Kashmir. Since the time when the plants and animals, of which the fossil remains are now found at 11,000 feet or even higher, flourished in and around this lake, the sediments have been *lifted out of their original horizontal position* and have been *upheared through at least five thousand feet with the (geologically speaking) recent up-hearal of the Pir Panjal Range.*"

The studies on the fossil fishes of the Karewas of Kashmir fully bear out Sahni's contention and afford further evidence of comparatively recent orogenic uplift movements in the Himalayas.

## IV.—SUMMARY.

Fossil fishes collected by Dr. H. de Terra from the 2nd Inter-glacial clay in the Kashmir valley comprise a piece of skin with scales, pharyngeal teeth, caudal portions of the skeleton, vertebrae and bits of dorsal spine. From the lepidosis and the structure of the scales, it has been possible to refer the entire material to the subfamily Schizothoracinae (Family: Cyprinidae). The detailed structure of the various parts shows that the fragments are referrable to the genera *Schizothorax* Heckel or *Oreinus* McClelland. From the present day distribution of these genera it is concluded that the fossils may have been laid down at the bottom of a lake or a large, sluggish river situated at an altitude of about 5,000 feet; their present position in the Ningal Nullah above Gulmarg at an altitude of 9,800 feet, therefore, affords evidence of recent orogenic uplift movements in the Himalayas.

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## VI.—EXPLANATION OF PLATE 14.

*Fossil Fish-Remains from the Karewas of Kashmir.*

FIG. 1.—A portion of the skin of specimen No. K40/241, showing lepidosis. $\times 11\frac{1}{5}$

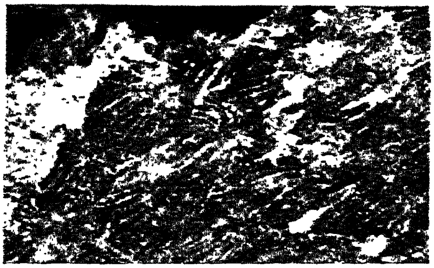
FIG. 2.—Same as above with the structure of scales better defined. $\times 11\frac{1}{5}$.

FIG. 3.—Pharyngeal teeth (Specimen No. K40/242). $\times 5\frac{3}{5}$.

FIG. 4.—Pharyngeal teeth further magnified. $\times 16$.

FIG. 5.—Skeleton of caudal region of a fossil fish (Specimen No. K40/243). $\times \frac{7}{8}$.

Fig. 6.—Skeleton of caudal region of *Oreinus sinuatus* (Heckel) for comparison with figure 5. $\times$ *ca* $\frac{3}{5}$.

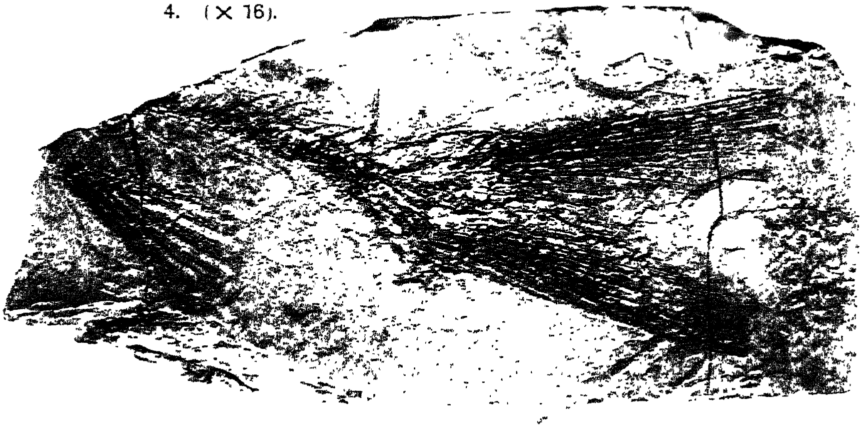


1. ($\times$ $11\frac{1}{5}$).

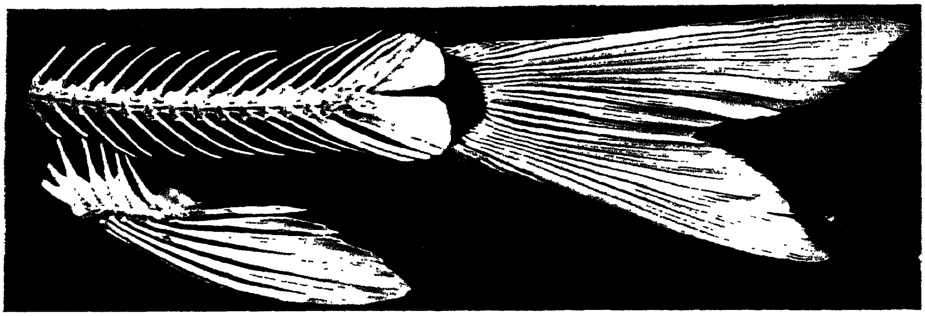
3. ($\times$ $5\frac{3}{5}$).

4. ($\times$ 16).

2. ($\times$ $11\frac{1}{5}$).



5. ($\times$ $\frac{2}{3}$).



6. ($\times$ *ca* $\frac{3}{5}$).

FOSSIL FISH REMAINS FROM THE KAREWAS OF KASHMIR.

*S. C. Mondal, Photos.*

# Fossil Fish-remains from the Saline Series of North-Western India. By Sunder Lal Hora, D.Sc., F.R.S.E., F.N.I., *Assistant Superintendent, Zoological Survey of India, Calcutta.* (With Plate 15.)*

A large number of small fossil fish-remains were obtained by Mr. E. R. Gee of the Geological Survey of India from "within the gypsum stage, at the top of the Saline series near Malgin (33° 19′ 30″ : 71° 31′ 30″), Kohat district" (Gee, E. R. The Saline Series of North-Western India. *Cur. Sci.*, II, p. 461, 1934). They were examined by Dr. E. I. White who reported them to be of the post-Cretaceous type. The material was later passed to me by the Director of the Geological Survey of India for a detailed examination and report. It is of a very fragmentary nature and its state of preservation is far from satisfactory. There is only one fairly complete specimen (G. S. I. Type No. 16361),[1] but even in this case the head region is very obscure. Taking the entire material into consideration, 4 types of fishes can be recognised. Of these one belongs to the family *Clupeidae*, one can be referred with some doubt to the family *Dorosomidae*, while the remaining two can only be assigned to the order *Percomorphi*. The Clupeid seems to be the most predominant form, as it is represented in the collection by a large number of fragments. A careful study of a series of these fragments has rendered it possible to determine this form specifically; while in the case of other fishes it has not been possible to identify them even generically. In the following account I propose to describe a few of the better preserved fragments and to discuss the probable affinities of each type.

Both the Herrings and the Perches date from the Cretaceous and are at the present day among the predominant families of the Teleostei. The probable genera represented in the collection are known only from the Tertiary formations. The fish-association, as represented by the fossil material, shows that the Saline series may have been laid down either in a lagoon, a bay, an estuary or near a sea shore. Clupeid fishes are very gregarious and often enter estuaries in vast shoals. Some species are known to breed in

* Published with permission of the Director, Zoological Survey of India.

[1] The number refers to the registered number of the specimen in the collection of the Geological Survey of India.

estuaries, and at certain seasons very large numbers of young forms swarm in these areas. The preponderance of the small Clupeid fishes in the material thus indicates the type of habitat in which the Saline series may have been laid down.

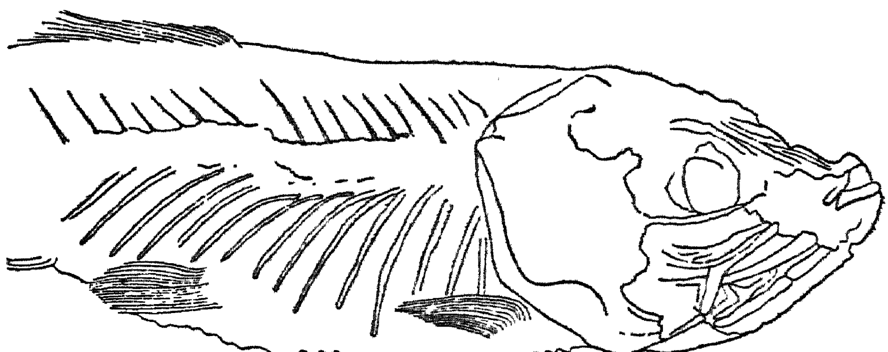
## Order: ISOSPONDYLI.

### Family: *CLUPEIDAE.*

### Subfamily: *CLUPEINAE.*

### **Clupea geei,** sp. nov.

*Specimen* G. S. I. Type No. 16359. Bones and impressions of a fish preserved in a slightly ventro-lateral view. (Plate XV, fig. 4 ; text-fig. 1.)



TEXT-FIG. 1.—*Clupea geei*, sp. nov. Outline drawing made from an enlarged photograph of specimen G. S. I. Type No. 16359. ×9.

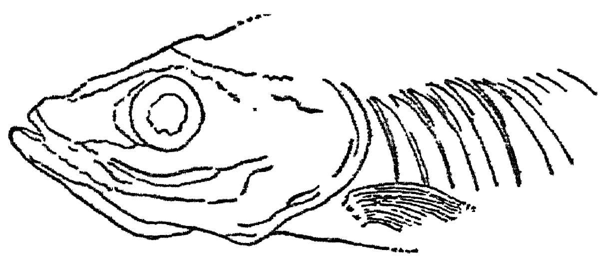
*Approximate measurements in millimetres.*

| | |
|---|---|
| Total length including caudal | 20·2 |
| Length of caudal . . | 4·2 |
| Length of head . . . | 5·0 |
| Depth of body . . . | 4·5 |
| | 2·0 |
| Diameter of eye | 1·2 |

In this specimen the bones and impressions of the head and the trunk region are clearly marked while those of the caudal region are obscure. The mouth is small and turned upwards. A small

portion of the head behind the mouth is obscure, while behind this region the maxillary and the supplemental bones are clearly indicated. These bones seem to extend below the middle or the hind border of the orbit. The eyes are lateral and are placed almost in the middle of the head. The neural spines and ribs are clearly marked in the anterior region. The dorsal fin commences in advance of the ventrals and its commencement is somewhat nearer to the tip of the snout than to the base of the caudal. It lies folded against the back and about 12 rays can be counted in it. The pectoral fin is considerably shorter than the head and contains about 12 rays. The ventral fins are well developed and each consists of eight rays. The anal fin is obscure; its commencement is situated behind the ventrals and about 8 rays can be made out in it with considerable difficulty. The caudal fin is bifurcate and both the lobes are pointed; it is shorter than the length of the head. The impression of the ventral edge of the body shows that the abdominal serrations commence before the base of the pectoral fin and are continued to the commencement of the anal fin.

*Specimen* G. S. I. Type No. 16360.—Bones of head and of anterior part of body preserved in lateral view (Plate XV, fig. 6; text-fig. 2).

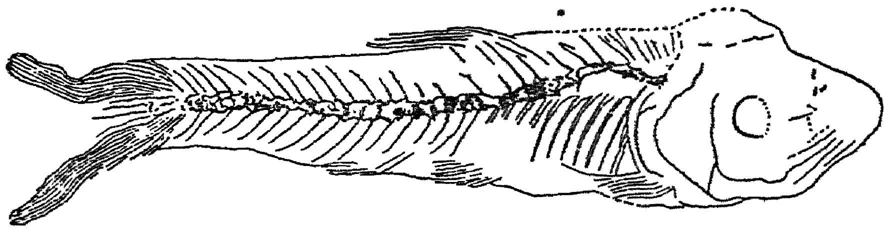


TEXT-FIG. 2. *Clupea geei*, sp. nov. Outline drawing made from an enlarged photograph of specimen G. S. I. Type No. 16360. ×7½.

The form of the head and mouth, the nature of the various bones and the position of the eye are similar to those described above for specimen G. S. I. Type No. 16359, except that this specimen is not preserved in ventro-lateral view. The area of the neural spines has been obscured by scratching, but the anterior ribs are very clear.

*Specimen* G. S. I. Type No. 16361.—A complete specimen preserved in lateral view, with the head region very obscure and the extremities of the dorsal, anal, pectoral and ventral fins not properly preserved. (Plate XV, fig. 5; text-fig. 3.)

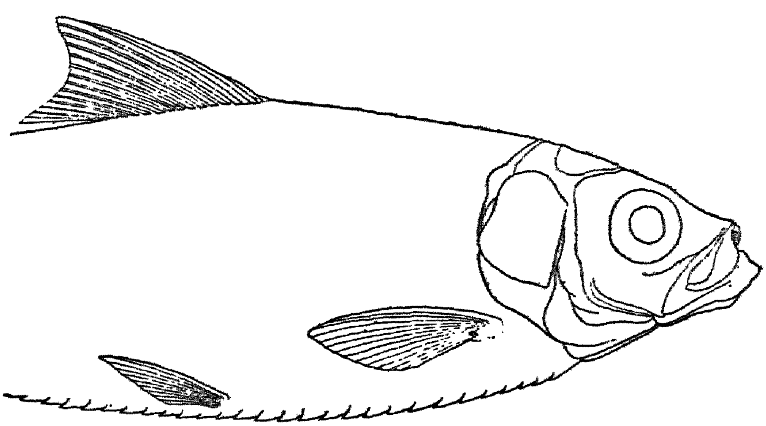
This specimen is about 22 mm. in total length. The vertebral column, which is out of position in the anterior part, is well-preserved; the neural spines and the ribs are clearly marked. The



TEXT-FIG. 3.—*Clupea geei*, sp. nov. Outline drawing made from an enlarged photograph of specimen G. S. I. Type No. 16361. ×5.

head region is greatly crushed and the structure of its various parts cannot be made out.

*Affinities*: *Clupea geei* probably represents a young stage of some species, but the nature of the material does not permit a close study of its relationships. Moreover, the young stages of all the Indian Clupeidae are not known. In view of this and on account of differences in proportions, number of fin rays, etc., between *C. geei* and the already known species it has been considered advisable to recognise the Clupeid of the Saline series as a distinct species and to associate it with the name of Mr. E. R. Gee who discovered it. The fossil species appears to be similar to the young stages of *Hilsa ilisha* (Ham.), the well known anadromous fish of India. For comparison the figure of a young specimen of *ilisha* in a slightly ventro-lateral view is given here (text-fig. 4).



TEXT-FIG. 4.—Head and trunk of a young specimen of *Hilsa ilisha* (Ham.) in slightly ventro-lateral view. ×3½.

According to Zittel, (*Text-book of Palaeontology*, II, 2nd Ed. p. 155, London: 1932) the species of *Clupea* are "Not certainly known below the Upper Eocene of Monte Bolca, near Verona." Fossils of the family Clupiedae are, however, known from the Cretaceous period.

Family: *DOROSOMIDAE.*

? **Dorosoma** sp.

*Specimen No.* K40/527 and its counterpart specimen No. K25/528, (Plate XV, fig. 3).

This is a small fish about 40 mm. in length, without the caudal, preserved in lateral view. The bones are obscured by the skin which is preserved with scales. The structure of the scales cannot be made out. From the nature of the snout, which is obtuse and seems to overhang the mouth, I doubtfully assign this specimen to the genus *Dorosoma*. The fins, with the exception of the proximal part of the caudal fin, are not preserved.

Species of *Dorosoma* are mud-eating fishes of the coasts and estuaries and one species *D. manminna* (Ham.) is very common in the estuaries of the large rivers of India.

Order: PERCOMORPHI.

*Specimen No.* K28/240.—An imperfect specimen, without the head region, preserved in lateral view. (Plate XV, fig. 1, text-fig. 5.)

TEXT-FIG. 5.—Trunk and tail region of a Percoid fish (specimen No. K28/240). ×4⅔. Outline drawing made from an enlarged photograph of the specimen.

This is a small fish about 27 mm. in total length without the head. The body skeleton is well preserved; the middle portion of the dorsal fin is, however, missing.

The body is short and deep. The vertebral column is composed of about 24 vertebrae, of which 11 to 12 are caudal. The dorsal fin extends almost along the entire length of the back; only 4 to 5 spines of its anterior spinous portion and about half-a-dozen soft rays of the posterior region are preserved. The anal fin is situated below the posterior part of the dorsal fin and is composed of 3 strong spines and a few soft rays. The caudal fin is rounded and contains about 15 rays. The paired fins are not preserved; there are, however, faint indications of their stumps.

*Affinities.*—In its general facies and the nature of its dorsal and anal fins the specimen seems to belong to the Perciformes. The presence of one continuous dorsal fin with the anterior portion composed of spines, three anal spines continuous with the rest of the anal fin and the rounded caudal fin indicate that the fish may belong to the family Serranidae. Representatives of this family and other Perches are known from the Tertiary formations of Europe and America.

*Specimen No.* K28/205 and its counterpart specimen No. K28/249 Caudal region of a small fish preserved in lateral view. (Plate XV, fig. 2; text-fig. 6.)

TEXT-FIG. 6.—Caudal region of a Percomorph fish (Specimen No. K28/205). ×3⅓. Outline drawing made from an enlarged photograph of the specimen.

In this imperfect specimen only the posterior portion of the dorsal fin, containing about 12 soft rays, is preserved. The anal fin is short and contains 3 spines and about 5 soft rays. The first spine is short while the second is probably the longest. The anal fin is situated below the posterior part of the dorsal fin. The caudal fin is deeply forked, with the two lobes pointed; it contains about 17 rays besides a few small ones at the sides.

*Affinities.*—From the very fragmentary nature of the specimen it is very difficult to assign it to any family. The nature of the anal and the caudal fins suggests that the fish may belong to the genus *Ambassis* Cuv. and Val., several species of which are found in the seas, brackish and fresh waters of the Indo-Pacific Region. Like its allied genus *Apogon* Lacép., *Ambassis* is probably not older than the Tertiary period of the earth's history.

## EXPLANATION OF PLATE 15.

FIG. 1.—Trunk and tail region of a Percoid fish (Specimen No. K28/240). ×3.

FIG. 2.—Caudal region of a Percomorph fish (Specimen No. K28/205). ×3.

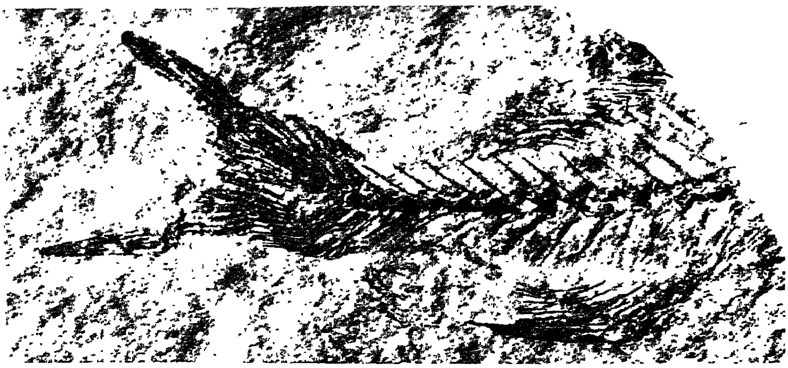
FIG. 3.—A Clupeoid fish, probably belonging to the genus *Dorosoma* Rafinesque. (Specimen No. K25/527). ×1½.

FIG. 4.—*Clupea geei*, sp. nov. (Specimen G. S. I. Type No. 16359). ×4½.

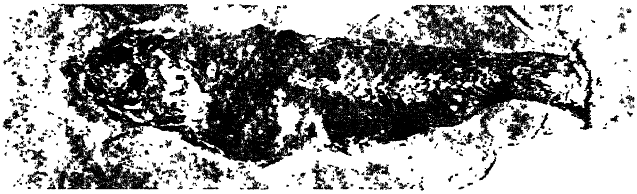
FIG. 5.—*Clupea geei*, sp. nov. (Specimen G. S. I. Type No. 16361). ×3.

FIG. 6.—*Clupea geei*, sp. nov. (Specimen G. S. I. Type No. 16360). ×3.

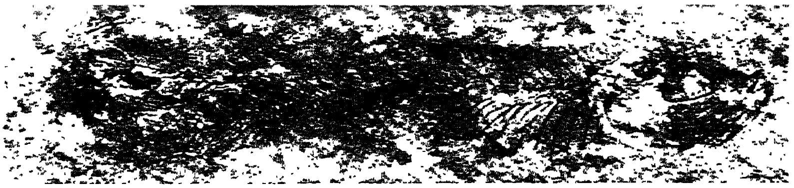
1. (× 3).



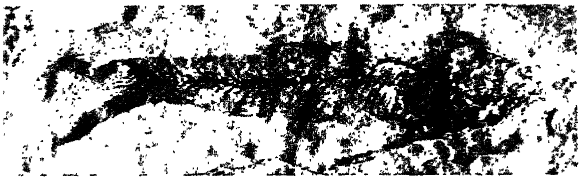
2. (× 3).



3. (× $1\frac{1}{2}$).



4. (× $4\frac{1}{2}$).



5. (× 3).

6. (× 3).

*S. C. Mondul, Photos.* *G. S. I., Calcutta.*

# RECORDS

of the

# INDIAN MUSEUM

Vol. XXXIX, Part III, pp. 241—250

## Comparison of the Fish-faunas of the Northern and the Southern faces of the Great Himalayan Range.

By

SUNDER LAL HORA

CALCUTTA:
SEPTEMBER 1937

# COMPARISON OF THE FISH-FAUNAS OF THE NORTHERN AND THE SOUTHERN FACES OF THE GREAT HIMALAYAN RANGE.

*By* SUNDER LAL HORA, D.Sc., F.R.S.E., F.N.I., *Assistant Superintendent, Zoological Survey of India, Calcutta.*

When Stewart[1] wrote a short article under the above title in the series of reports on a collection of aquatic animals made by him in Tibet during the year 1907, he was probably not aware that Day[2] had already compared in some detail the fish fauna of the highlands of Central Asia with that of the contiguous regions. In this connection Day made a survey of the fishes of Afghanistan, Western Turkestan, Eastern Turkestan, Yarkand, Tibet and Hindustan and concluded as follows (p. 25):

"The conclusion, I think, we may fairly arrive at after examining the fishes of Yarkand and the adjoining countries, is that we find a peculiar group of Carps (Schizothoracinae) which has spread almost due east and west from the cold and elevated regions of Eastern Turkestan, but of which the southern progress has been barred by the Himalayas."

"If we look to the south, we see, as it were, that a wave of tropical forms of fishes has, at a prehistoric period, expanded over that portion of the globe where the Nicobars, Andamans, and the most southern portions of the continent of Asia and the islands of the Malay Archipelago now are, that this fish fauna has its northward progress arrested by some cause at or near where the Himalayas now exist and mark the division between the fish-fauna of India and that of Turkestan."

Stewart's data for the comparison of the two faunas were based on the records of distribution of the various Indian species in Day's volumes in the "Fauna of British India" series and on the species described by Regan[3] and Lloyd[4] from Eastern Tibet. He found that

"From the northern area seventeen species of fish are at present known, belonging to the families Siluridae and Cyprinidae. From the southern area thirty-six species of these two families are recorded in the *Fauna of British India*. These two groups have only two species in common (*Schizothorax esocinus* and *Diptychus maculatus*).[5] (These two species are also the only forms from the Trans-Himalayan Indus which have not hitherto been found in the Trans-Himalayan Brahmaputra. Thus there are no species common to the latter and to the rivers of the south face of the Himalayas). Thus of these two families there are fifteen species confined to the northern regions, thirty-four to the southern, and two are found in both."

It may, however, be noted that while Day's conclusions are based on a study of the forms occurring to the north and the south of the western portion of the Himalayas, Stewart's remarks relate to the forms found in the eastern portion of that great range. Both these authorities are, however, in complete agreement that there is no similarity between the

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[1] Stewart, F. H.—Comparison of the fish fauna of the north and the south faces of the great Himalayan range. *Rec. Ind. Mus.*, III, pp. 121-123 (1909).

[2] Day, F.—*Scientific Results of the Second Yarkand Mission*. Ichthyology, pp. 1-25 (Calcutta: 1878).

[3] Regan, C. Tate.—Descriptions of five new Cyprinid fishes from Lhasa, Tibet. *Ann. Mag. Nat. Hist.*, (7) XV, p. 185 (1905); Descriptions of two new Cyprinid fishes from Tibet. *Ibid.* (7), XV, p. 300 (1905).

[4] Lloyd, R. E.—Report on the fish collected in Tibet by Capt. F. H. Stewart, I.M.S., *Rec. Ind. Mus.*, II, pp. 341-346 (1908).

[5] The known distributional records of *Schizothorax esocinus* Heckel and *Diptychus maculatus* Steind show that these species do not occur on the south face of the Himalayas and are typical members of the Central Asiatic fauna.

fish-fauna of the northern and the southern faces of the great Himalayan range. This conclusion appears to be based mainly on the distribution of the Schizothoracinae, and it is, therefore, of interest to examine the two faunas more closely.

FISH OF CENTRAL ASIA AND OF INDIA.

By " Central Asia " I mean the highlands bordered on the north by the Tien Shan Mountains and on the south by the north face of the Himalayas. To the west, where the Himalayan range does not extend, the Hindu Kush range forms the northern boundary while the southern and western boundaries are ill-defined. Towards the east of the headwaters of the Hwang Ho and the Yangtze Kiang form an undefined boundary. Within these limits are included the headwaters of the Jaxartes and the Oxus, the basins of the Hari Rud and the Helmund, the Trans-Himalayan portions of the Indus and the Brahmaputra, the Tarim Basin, the basin of Lake Balkash, the Mongolian Lake Basin and Tsaidam. The fauna of this vast territory, except near the fringes towards the east,[1] and the west,[2] is composed of the Schizothoracinae, of the catfishes of the genus *Glyptosternum* McClelland (Family : Sisoridae) and of the loaches of the genus *Nemachilus* van Hass. (Family : Cobitidae). Of these three types of fishes, the genus *Nemachilus* is the most widely distributed, as it is found not only throughout the Oriental Region, but its range extends to Africa as well. Though this genus is equally abundant in the northern and southern territories of the Himalayas, the species of the two regions are so different from one another that they can be readily distinguished.[3] The Trans-Himalayan species usually grow to a fairly large size ; the body is greatly elongated and almost whip-like posteriorly. The skin is totally devoid of scales. The colour on the sides forms a mottled pattern. The species of the Indian region are usually small in size and possess short, stumpy bodies. Small scales, sometimes hidden in the skin, are usually present, while the body is invariably marked by a series of transverse bands.. Several attempts have been made to subdivide the fishes of this genus, but from an intensive study of extensive material from the northern and the southern faces of the Himalayas I have not been able to discover any reliable characters for separating the groups recognised as genera by other workers. In spite of the great difference in the appearance of the

[1] In my account of the " Fish of Afghanistan " (*Journ. Bombay Nat. Hist. Soc.*, XXXVI, pp. 688-706, 1933) I gave a short review of the types of fishes found in Waziristan, Baluchistan, Seistan, Chitral ; the Pamirs and the Kashmir and in an addendum some further details are given on the information supplied by Prof. L. S. Berg. It will be seen how, with the exception of Chitral and the Pamirs, the Central Asiatic fauna becomes less marked as we move away from the central zone.

[2] In the lists of Chinese fishes given by Professor Tamezo Mori in his recent work entitled " Studies on the Geographical Distribution of Fresh water Fishes in Eastern Asia " (Chosen : 1936), we find that only one species of *Schizopygopsis* Steindachner is listed from Hoang-Ho, three species of *Schizothorax* Heckel, five species of *Oreinus* McClelland and two species of *Schizopygopsis* from the Yangtze Kiang and two species of *Schizothorax* and three species of *Oreinus* from Southern China. There is a considerable mixture of the Schizothoracine element with the typical Oriental forms in Szechuan, Yunnan and South China.

[3] Hora, S. L.—On Fishes belonging to the family Cobitidae from high altitudes in Central Asia. *Rec. Ind. Mus.*, XXIV, pp. 63-83 (1922).

northern and the southern forms there can be no doubt regarding the genetic affinity of the two types.

The Central Asiatic group of species can be divided ecologically into two categories,[1] (i) those that live in shallow, rapid-running waters and (ii) those that live in lakes. The lake-forms possess a secondarily developed large air-bladder in addition to the original structure enclosed in two bony capsules. The free air-bladder referred to above is, in my opinion, a secondary acquisition developed as an adaptation to life in deeper waters. The form of the free air-bladder is so varied that it is difficult to resist the conclusion that the production of a secondary free air-bladder in certain species of *Nemachilus* has independently occurred again and again in different lakes of Central Asia—the presence of intermediate forms in shallow, sluggish waters lends support to this hypothesis On the southern face of the Himalayas there are no large lakes and even the small ones that exist are probably not of any great antiquity, since they do not possess any endemic faunas. The lakes of northern Burma,[2] however, are of considerable age, as their fish faunas are characterised by several abberant and highly interesting indigenous forms. In this region we get certain species of *Nemachilus* which have developed a secondary air-bladder[3] but their general build is similar to that of the forms found in India. It may be concluded from the above that the Nemachili of the north and the south faces of the Himalayan range, though genetically identical, represent totally different races.

There are only two species of the genus *Glyptosternum*, *G. reticulatum* McClelland and *G. maculatum* (Regan). The latter is known from Eastern Tibet, while the former is widely distributed in the upper reaches of the Indus, the Kabul, the Amu-Darya and the Syr-Darya Rivers. There is reason to believe that the two species have been produced as a result of isolation and segregation of a once widely distributed ancestral stock. A great variety of Glyptosternoid fishes is found in Siam, Yunnan, Burma and the Brahmaputra drainage of India[4]. Recently I[5] have suggested the probable origin of the Glyptosternoid fishes from *Pseudecheneis*-like ancestral forms, but whatever may be the origin of these interesting fishes there can be no doubt that the Trans-Himalayan *Glyptosternum* has its nearest allies in Siam, Yunnan, Burma and north-east India. Here again, though we find a close genetic similarity between the Himalayan and the Trans-Himalayan species, the diversity of form is so pronounced that the two faunas must be regarded as distinct.

The Schizothoracinae are small-scaled Barbels with their nearest allies in the so-called large-scaled or moderate-scaled Barbels of the

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[1] Hora, S. L.—Report on Fishes of the Yale North India Expedition. Part I: Cobitidae. *Mem. Conn. Acad.*, X, pp. 299-305 (1936).

[2] Annandale, N.—Fish and Fisheries of the Inle Lake. *Rec. Ind. Mus.*, XIV, pp. 33-64 (1918); Prashad, B. and Mukerji, D. D. *Rec. Ind. Mus.*, XXXI, pp. 161-223 (1929).

[3] Hora, S. L.—The Value of Field Observations in the Study of Organic Evolution. *Journ. Bombay Nat. Hist. Soc.*, XXXIV, pp. 377, 378, 382 (1930).

[4] The distribution of the Glyptosternoid fishes is as follows: *Oreoglanis* Smith in Siam; *Glaridoglanis* Norman in Yunnan; *Euchiloglanis* Regan in Tonkin, China, Burma and the Brahmaputra drainage of India; *Exostoma* Blyth (used in its broadly accepted sense) in Burma and *Glyptosternum* McClelland in Kashmir, Turkestan and Tibet.

[5] Hora, S. L.—On a New Genus of Chinese Catfishes allied to *Pseudecheneis* Blyth. (In press.)

Oriental and the Aethiopian regions. Both kinds of Barbels occur in diverse types of habitats—from strong currents to muddy pools—and have consequently become differentiated into a variety of closely related genera, which are often very difficult to distinguish from one another. The Schizothoracinae are distinguished from the Cyprininae by the possession of minute scales but in some cases the scales are entirely absent. A membranous sac or slit anterior to the anal fin, which is laterally bounded by a row of vertically placed scales, like eave-tiles, and which are continued along the base of the anal fin, is also characteristic of the Schizothoracinae. On the southern face of the Himalayas, this subfamily is represented by the genus *Oreinus* McClelland which is spread from Afghanistan along the whole Himalayan and contiguous ranges of hills to south-eastern China. So far as is known, these fishes appear to be strictly residents of rivers in the hilly regions, neither descending far into the plains nor occurring in the level plateaux on the summits of the mountains. Their mouth is armed with a special adhesive device which enables them to resist the rapid currents of the torrential streams. Though *Oreinus* is a well recognised morphological genus, there is every reason to believe that it represents only specialised members of the genus *Schizothorax* Heckel.[1] The two genera interbreed very freely and in several large collections intermediate forms between *Schizothorax* and *Oreinus* are not uncommon. Several Himalayan rivers have Trans-Himalayan sources and it is along these channels that *Oreinus*, a representative of the Schizothoracinae, has probably come down during floods, etc., to the Himalayan rivers. No other genus of this subfamily is found in the small torrential streams of the Himalayas. Tchang[2] has recently described two species of *Barbus* Cuvier from Yunnan, *B. regani* and *B. normani* in which the scales are minute and their general build is very much like the Schizothoracinae, except that they do not possess the tiled rows of scales in front of and at the sides of the anal fin. It thus seems likely that such species of *Barbus* were the progenitors of the Schizothoracinae. In the case of the Schizothoracinae, therefore, we have specially modified Oriental Barbels, but the differences between the two types of Barbels are sufficiently well marked for distinguishing the fish faunas of the northern and the southern faces of the Himalayas.

The great variety of other Catfishes and Carps that characterise the aquatic fauna of the southern face of the Himalayas is not at all represented on the northern face of the range.

## PHYSICAL FACTORS AND THE CHARACTERISTIC FEATURES OF THE TWO FAUNAS.

In an account of the 'Ecology, Bionomics and Evolution of the Torrential Fauna'[3] it was shown that the physical factors of an environment play a great part in the association of the fauna of a particular

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[1] Hora, S. L.—The Fish of Chitral. *Rec. Ind. Mus.*, XXXVI, pp. 307-310 (1934).

[2] Tchang, T. L.—Two New Species of *Barbus* from Yunnan. *Bull. Fan Mem. Inst. Biology*, (Zool.), VI, pp. 60-63 (1935).

[3] Hora, S. L.—Ecology, Bionomics and Evolution of the Torrential Fauna, with special reference to the organs of attachment. *Phil. Trans. Roy. Soc. London*, (B), CCXVIII, pp. 171-282 (1930).

habitat. Having shown that the fish faunas of the northern and the southern faces of the Himalayan range are almost totally different, though genetically closely related, we may enquire into the factors governing the habitats of the two faunas.

Stewart (*op. cit.*) gave the following four principal physical characteristics of the Central Asiatic region :—(i) its great elevation (usually over 10,000 ft.); (ii) its very low rainfall; (iii) sparse vegetation and (iv) the rapidity of flow of streams. From the point of view of the conditions that govern fish life, the first three factors are of little significance. For instance, the Schizothoracinae are not confined only to high altitudes but are also known from low elevations (for example Seistan, where *Schizothorax* and *Schizocypris* Regan occur, is situated in a deep depression less than 2,000 feet above sea level). It is also immaterial for fish life whether the water in a particular stream is derived from rainfall, glaciers or from springs, as fishes become gradually acclimatised to changes in temperature. Most of the hill-stream fishes feed on insect larvae or aquatic vegetation (mostly slimy algae adhering to rocks and stones), and it is no consequence whether the terrestrial vegetation of the area is sparse or thick. The nature of the river bed and the swiftness of the current are, however, important factors.

It is a general characteristic of the highlands of Central Asia that the rivers run with some rapidity in broad beds of boulders and often expand into marshes and lakelets. Further there are lakes of considerable magnitude dotted all over this area. For an understanding of the correlation between the type of habitat and the corresponding fauna reference may be made to my account of the fish of Chitral cited above. On the southern face of the Himalayas the streams are small and precipitous and there are no large lakes. The nature of the streams is so torrential that very few species of fish are found above an altitude of about 4,000 ft.; the greatly diversified fish-fauna of this region is mainly restricted to valleys. On the southern face of the Himalayas, therefore, fishes require mechanical devices to enable them to withstand the rapidity of the currents, such forms are *Garra* Hamilton, *Glyptothorax* Blyth, *Pseudecheneis* Blyth, etc., which do not grow to a large size, while some, like *Balitora* Gray, are greatly flattened. In the large rivers and lakes of the highlands of Central Asia the conditions of life are presumably not so rigorous and in consequence the rivers are stated by every observer to be teeming with fish life. The fish grow to a fairly large size and are trout-like in appearance, with the exception of *Glyptosternum* which is flattened and is found clinging to rocks, etc.

The most striking feature of the fishes of Central Asia, however, is the degenerate nature of their scales,[1] culminating in their total absence in some forms. As in the Salmonidae, the smallness of the scales in the Schizothoracinae is probably due to the necessity for a supple integument whether in fast-swimming fishes or in those that live in smooth, rapid-running waters, for it must be remembered that whether a fish moves through water swiftly or the water glides over it with great rapidity the physical factors involved are the same in both

[1] Annandale, N. and Hora, S. L.—The Fish of Seistan. *Rec. Ind. Mus.*, XVIII, p. 154 (1920).

cases. A remarkable feature of the Schizothoracinae is the anal sheath of scales. Besides these enlarged scales, there are usually somewhat larger scales in the scapular region, at the bases of the dorsal and ventral fins and along the lateral line. As the fish moves through the water, these are precisely the regions where, owing to protection afforded by the conical head, fins, and the stream-lined body of the fish, the tearing-away action of the current is least felt. In consequence, these scales do not undergo degeneration to the same extent as on the parts of the body more exposed to the currents. It seems logical, therefore, to assume that the whole of the fish-fauna of the highlands of Central Asia has been modelled to suit the peculiar conditions of the rivers of that region. *Schizothorax*, the perfectly scaled member of the Schizothoracinae, is found in lakes and in large rivers with backwaters,[1] while other genera of the subfamily with scales in varying degree of reduction live in swift waters of varying rapidity.

Along the southern face of the Himalayan range, on the other hand, though the streams are more torrential, we have forms with larger scales. In fact, the *Barbus tor* group, constituting the renowned 'Mahseers' of India, is well represented in the Himalayas and even in *Garra*, which possesses a true vacuum sucker, the body is provided with moderately large scales. The same is true of such mountain genera as *Balitora*, *Psilorhynchus* McClelland, *Crossochilus* van Hass., etc. Even the Siluroids, which live on the exposed surfaces of rocks, such as *Sisor* Hamilton, *Glyptothorax*, *Laguvia* Hora, *Erethistes* Müll. & Trosch., etc., have developed wart-like, hard projections on the skin. This may seem contradictory to what has been stated above regarding the reduction of scales in Central Asiatic fishes, but in reality it is not so. In dealing with the physics of the mechanism of attachment in hill-stream animals it was shown[2] that though at certain velocities the resistance of a body subjected to a current is greatly reduced by the rounding-off of its contours, at other velocities, in some bodies, such as spheres and cylinders, the resistance is actually reduced by the roughening of the surface. Those who have visited the Trans-Himalayan and the Cis-Himalayan areas of the great range will bear out very fully that the nature of the flow of water currents in the two areas differs very considerably. It is these differences in the nature of the currents that account for the different types of fish-fauna of the two regions.

## ORIGIN OF THE TWO FAUNAS.

According to Day (*vide supra*, p. 241) at some very early age the Himalayas acted as a barrier between the northern and the southern forms and the resulting isolation kept the two faunas very distinct. This is true so far as it goes and certainly at the present day the Himalayan range is an effective barrier that does not permit the northern and the southern fish-faunas to intermingle. It has been shown above that

[1] Hora, S. L. and Mukerji, D. D.—Pisces in *Visser's Karakorum*, I, pp. 427, 428 (Leiden: 1935).

[2] Hora, S. L.—Ecology, Bionomics and Evolution of the Torrential Fauna, with special reference to the organs of attachment. *Phil. Trans. Roy. Soc. London* (B), CCXVIII, pp. 254-256 (1930).

the Central Asiatic *Glyptosternum* and *Schizothorax* have their close allies in Yunnan and the adjoining territories of south-eastern Asia. It seems reasonable, therefore, to infer that the fish-fauna of Central Asia was derived from an eastern stock, as I[1] have suggested in regard to the origin of the fish-fauna of India as a whole. The close genetic similarity between the two faunas is undoubtedly due to their common origin, and the dissimilarity between them is probably due to their differentiation in different geological ages, long isolation and the resulting segregation. Attention may here be directed to Regan's[2] hypothesis "that as a rule the first step in the origin of a new species is the formation of a community with a new and restricted environment, or with new habits; in other words, that some form of isolation, either localization or habitudinal segregation, is the condition of the development of a new species." What is true of the species is also applicable to faunas as a whole. The fish-fauna of Central Asia, at any rate, affords a remarkable instance in support of this hypothesis.

To compare the origin of the Trans-Himalayan and the Cis-Himalayan fish-faunas it seems worth while to give a very brief account of the geological history of the Himalaya, but unfortunately our knowledge of Trans-Himalayan geology is very meagre indeed.

"There is no evidence to show that the Himalaya, as a great mountain range, are older than the latter part of the Eocene period".[3] Before that the Himalayan area formed the northern coast of Gondwanaland and a number of rivers flowed northward into the Tethys Sea of that period. The orogenic movement, which was strongly pronounced during the Oligocene, probably began in late Cretaceous times and continued throughout the Eocene and Middle Tertiary periods. There is considerable evidence to show that it was still active during the Pliocene and the later periods. The ossiferous beds of Ngari Khorsum and of the Karewas of Kashmir, however, indicate that during the Pleistocene period the Himalayas had already acquired the general features of their present-day form. The nature of the Siwalik deposits shows that the main drainage lines on the south face of the Himalayas date as far back as the Pliocene epoch and that "the rivers which brought down the sands and boulders from the mountains to build up the Siwaliks of the Duns and the Hundes were the direct ancestors of our modern Sutlej and Ganges."

From the generalised nature of the Trans-Himalayan fish-fauna it may be surmised that the eastern portion of the Tibetan plateau was the first area to be lifted and raised above the neighbouring Chinese territory. The drainage of this new land joined the then existing drainage of southern China and thus channels were established for the Chinese forms to colonise new lands. As the crustal movements gradually lifted the Tibetan region, better adapted hill-stream forms

[1] Hora, S. L.—Geographical Distribution of Indian Freshwater Fishes and its bearing on the Probable Land Connections between India and the Adjacent Countries. *Curr. Sci.*, V, pp. 351-356 (1937).

[2] Regan, C. Tate.—Mendelism and Evolution. *Nature*, CXIII, p. 569 (1924).

[3] For geographical and geological facts about the history of the Himalayas I am indebted to Burrard and Hayden's "A Sketch of the Geography and Geology of the Himalaya Mountains and Tibet" revised by Burrard and Heron (Delhi: 1933).

were able to invade the higher reaches of these streams. The association of the fish-fauna shows that these rivers had fairly broad valleys with deep beds of boulder and rapid-running currents. It has then to be presumed that at a certain period a localised disturbance caused this region to be lifted up so as to isolate the fauna of this area from the ancestral stock. The geographical distribution of the Schizothoracinae shows that the waters of Central Asia may have flowed at first towards the east, then towards the west and north before the present drainage pattern was established.

"On the basis of his geomorphological studies, Dr. de Terra has reconstructed the Tertiary drainage pattern of the western part of the Tibetan plateau. A number of rivers ran from west to east, one of them occupying the present valley of the Upper Indus. It is difficult to resist the conclusion that a similar pattern extended farther north, the Tarim basin draining into the Hwang-ho."[1] According to Burrard, Hayden and Heron[2], the evidence furnished by the feeders of the Trans-Himalayan Brahmaputra shows that the Tsangpo formerly flowed through Tibet from east to west, and that of the great rivers of the world, "the Brahmaputra furnishes the only instance of drainage flowing in a diametrically opposite direction to what it formerly did, though still occupying the same bed."

The Schizothoracinae are at present found in at least twelve major river systems and numerous closed basins adjoining the plateau of Central Asia. *Glyptosternum* is also found in the eastward and westward flowing rivers. Mukerji and I[3] found the same species of *Nemachilus* in the headwaters of the Indus and the Karakash rivers. These facts concerning the geographical distribution of Central Asiatic fishes can only be explained reasonably on the assumption that after the establishment of the typical highland fish fauna local upheavals repeatedly led to changes in the drainage pattern of this region and thus made possible the wide dispersal of these forms.

So in the origin and distribution of the fish-fauna of Central Asia, the first step was the colonisation of the newly produced lands of Eastern Tibet, probably during the post-Eocene period, by the fauna of southern China, particularly of Yunnan. The second step was the lifting of this region, which resulted in the isolation of the fauna of the upper reaches by the reversal of the drainage system, and finally through localised orogenic movements in the region of the Tibetan trough the drainage pattern was made to oscillate from time to time resulting in the wide dispersal of the Central Asiatic forms within the limits of the trough defined above.

As indicated above, the fish of the southern face of the Himalayas are highly specialised and appear to have spread over this region from the east at a somewhat later date, possibly in the late Miocene or Pliocene periods. Of the hill-stream fishes of this region we have fossil records of *Bagarius* Bleeker, a widely distributed genus of the somewhat larger

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[1] Hutchinson, G. E.—Yale North India Expedition. *Nature*, CXXXIV, p. 87 (1934).

[2] Burrard, S. G. and Hayden, H. H.—*A Sketch of the Geography and Geology of the Himalaya Mountains and Tibet.* 2nd Edition, revised by Burrard, S. G. and Heron, A. M. (Delhi: 1933).

[3] Hora, S. L. and Mukerji, D. D.—Pisces in *Visser's Karakorum* I, pp. 427-428 (1935).

rivers of India, Burma and the Malay Archipelago, from the Siwalik formations of Nahan and the Tertiary formations of Padang in Sumatra. All students of Oriental fishes are familiar with the great similarity between the south Himalayan fish fauna and that of Burma, Siam, the Malay Peninsula and the Archipelago and Indo-China. In another place I[1] discussed the probable origin of the fish fauna of India and showed that it was derived from the eastern countries. For the probable mode of dispersal of fishes from east to west reference may be made to Gregory[2] and Gregory and Gregory[3] who have attempted to demonstrate that in south-eastern Asia the western rivers beheaded the rivers on the east; thus effecting the transference of eastern fauna towards the west. As the total Himalayan uplift was accomplished in three or more stages, every wave of orogenic movement may have affected the drainage pattern of that period, but, as evidenced by the distribution of freshwater fishes, it seems that every time the western rivers captured the waters of the eastern rivers. Changes in the drainage of the southern face of the Himalayas may also have resulted from localised disturbances. At any rate, it seems certain that when the South Chinese fauna began to spread along the southern face of the Himalayas, even the parental stock in China had probably already undergone considerable changes due to the torrential nature of the streams on the newly produced precipitous hill-sides.

It is thus seen that though the fauna of the northern and the southern faces of the Himalayas is derived from the same source, the Central Asiatic fauna, comprising comparatively less specialised forms, was probably differentiated at an earlier date when the parental stock was of a generalised nature; while that of the southern face of the Himalayas, comprising highly specialised forms, was produced at a later date when the original stock had already become fairly well adapted for life in torrential streams.

## Summary.

Attention is directed to the conclusions reached by Day and Stewart as a result of the comparison of the fauna on the northern and southern faces of the Himalayan range. From a critical examination of the fish of Central Asia and of India evidence is adduced in support of the earlier conclusions that the two fish faunas are very distinct from each other. The physical factors governing fish life in Central Asia and on the southern face of the Himalayas are discussed and it is shown that the fish of the two regions are adapted to suit the nature of their respective streams. The characteristic features of the two fish faunas are examined and their close correlation to environmental factors is indicated. The probable origin of the two faunas is described and it is shown that though the

[1] Hora, S. L.—Geographical Distribution of Indian Freshwater Fishes and its bearing on the Probable Land Connections between India and the Adjacent Countries. *Curr. Sci.*, V, pp. 351-356 (1937).

[2] Gregory, J. W.—The Evolution of the River System of South-Eastern Asia. *Scottish Geog. Mag.*, XLI, pp. 129-141 (1925).

[3] Gregory, J. W. and Gregory C. J.—The Alps of Chinese Tibet and their Geographical Relations. *Geog. Journ.*, LXI, pp. 153-179 (1923).

Central Asiatic and the Indian faunas are derived from the same source in south-eastern Asia, especially Yunnan, the former probably became differentiated at an earlier age when the parental stock was of a generalised nature, whereas the fauna of the southern face of the Himalayas was derived from a younger and more vigorous stock which had already become specialised in south-eastern Asia for life in torrential streams.

# RECORDS

of the

# INDIAN MUSEUM

Vol. XL, Part II, pp. 169—181

# Notes on Fishes in the Indian Museum. XXXVI. On a Collection of Fish from the Rajmahal Hills, Santal Parganas (Bihar).

By

SUNDER LAL HORA

CALCUTTA:

JUNE, 1938

# NOTES ON FISHES IN THE INDIAN MUSEUM.

## XXXVI. On a Collection of Fish from the Rajmahal Hills, Santal Parganas, Bihar.

By Sunder Lal Hora, D.Sc., F.R.S.E., F.N.I., *Assistant Superintendent, Zoological Survey of India, Calcutta.*

### Introduction.

One of the zoogeographical riddles in connection with the distribution of Indian freshwater fishes is the occurrence of similar forms, such as the Homalopteridae, *Silurus* Linn., etc., in the south-western hills of Peninsular India on the one hand, and in the Eastern Himalayas, Assam Hills, Burma and further east and south on the other. Such characteristic forms have not been found to occur along the Himalayan range beyond the Tista river water-shed, and this fact has been explained by me[1] recently by supposing that through a differential orogenic movement, which probably occurred late in the Miocene period or even later, a barrier was created between the eastern and the western Himalayan fishes. After this movement " The new stock of specialised hill-stream fishes from the east, not finding means to cross the barrier, were deflected towards south-west along the Satpura Trend which probably at this period stretched across India as a pronounced range from Gujrat to the Assam Himalayas ". With a view to test this hypothesis Dr. B. Prashad, Director, Zoological Survey of India, at the author's request, very kindly sent a party of the Zoological Survey of India under Drs. H. S. Rao and H. A. Hafiz in February-March, 1938, to survey the fauna of the Rajmahal Hills. The collection dealt with in this paper was made by this party both in the northern parts of the hills and on the bank of the Ganges at Sakrigali Ghat.

The Rajmahal Hills stretch from Sahibganj on the Ganges to Nangalbanga on the Rampur Hat and " consist of a succession of hills, plateaux, valleys and ravines, the general elevation of which varies from 500 to 800 feet above sea-level, though some hills have an altitude of 1,500 feet and a few are said to rise to the height of 2,000 feet. The valley is drained by the river Morel or Moran, which, flowing from the north, has scoured out a long ravine, and by the Gumāni coming from the south-west through the Chaparbhitā pass. These rivers meet at Burhait, and the united stream, which is called the Gumāni, flows along the Ghātiāri pass, and thence through the plains to the Ganges " [2]. Most of the collection was made in the valleys of these rivers and their side

[1] Hora, S. L.—*Rec. Ind. Mus.*, XXXIX, p. 255 (1937).
[2] O'Malley, L. S. S—*Bengal District Gazetteers.* Santal Parganas, p. 3 (Calcutta : 1910).

streams, but mention may also be made of Motijharna, a picturesque water-fall, which was also visited by the party.

At the time of the visit of the Zoological Survey party certain streams, like the one near Sundarpahari, were practically dry, while the relatively large streams, like the Gumāni river, had a shallow channel in the middle or on the sides meandering through the sand with only ankle-deep water in several parts. Streams, like the Morel, with banks had pools and puddles with a small trickle of water over a pebbly bed connecting them. The bottom of the pools, where muddy, was covered with aquatic vegetation and, where rocky, with *Spirogyra* and other algae. The muddy, rocky and pebbly portions occurred alternately according to the nature of the country over which the stream flowed. In the Gumāni the bed consisted mostly of coarse to fine sand except in bends of the river where the bottom was muddy. In the Morel, though the water mostly flowed over a muddy bed, in places the substratum consisted of pebbles and shingle.

One remarkable feature of the fish collection is the presence of a very large number of young specimens of practically all the species obtained by the party and particularly of *Barilius*, *Brachydanio*, *Barbus*, etc. From this it may safely be inferred that this is probably the breeding season of the fish found in the hills.

Of the 34 species of fish obtained by the party, 16 (*vide* list on p. 171), represent the common Gangetic forms. Six of these, were also obtained from the hill area, but all the sixteen species are widely distributed and from a zoogeographical point of view do not call for any comments. The occurrence of the very young specimens of *Gadusia chapra* in the Ganges at Sakrigali Ghat shows that the fish breeds high up in the Ganges and that the breeding season extends at least up to January-March.

Of the 18 species found only in the hills, ten, *viz.*, *Chela phulo*, *Esomus danricus*, *Catla catla*, *Aspidoparia morar*, *Nandus nandus*, *Ophicephalus gachua*, *Mastacembelus armatus*, *Lepidocephalichthys guntea*, *Barbus ticto*, *Brachydanio rerio* and *Barilius bendelisis*, are very widely distributed in Indian waters. *Barbus chagunio*, *Botia dario*, *Nemachilus zonatus*, and *Gagata cenia* are primarily north Indian forms and occur along the base of the Himalayas, but they have also been recorded from Orissa. *Amblyceps mangois* is found at the bases of hills from Siam, Burma, Assam Hills and the Himalayas as far west as the Kangra Valley and its occurrence in the Rajmahal Hills to the west of the Ganges is of special significance. Similarly *Garra gotyla* is essentially a Himalayan species. The most interesting find in the collection, however, is the presence of two specimens of *Laguvia ribieroi* Hora, a form described from the Eastern Himalayas several years ago and so far known from a single specimen.

Under the ecological conditions prevailing in the Rajmahal Hills of to-day, the presence of the typical torrential forms, which require a continuous flow of water over a rocky bed, was not to be expected, but the presence of *Laguvia*, *Amblyceps*, *Garra gotyla* and *Botia dario* has undoubtedly demonstrated the continuity of the fauna of the Rajmahal Hills with that of the hills of Assam. It has to be borne in mind

that the Rajmahal Hills of to-day are mere stumps of a once mighty range which probably had a great influence on the rainfall in India and harboured perennial torrential streams along which forms like the Homalopteridae, *Silurus*, etc., migrated at a time when the Ganges did not flow eastwards. On this last point Holdich (*vide* O'Malley, *op. cit.*, p. 6) says :—

> "There was no Gangetic basin in those days, and it was probable that Rajmahal Hills and the hills of Assam continued the land area to the Himalayas east of Sikkim. Another result of this succession of earth movements was the formation of that great Indo-Gangetic depression which forms one of the natural geographical divisions of India. The break in the connection between the Rajmahal and Assam hills, which gave an opening for the eastward flow of the Ganges, is comparatively recent."

Wadia[1] has shown that the change in the direction of flow of the Ganges probably occurred as a result of the Potwar movement during the Pleistocene period.

## LIST OF SPECIES.

Family CLUPEIDAE.

1. *Gadusia chapra* (Ham.)*

Family MASTACEMBELIDAE.

2. *Mastacembelus armatus* (Lacép.)

Family CYPRINIDAE.

3. *Chela clupeoides* (Bloch)*†
4. *Chela phulo* (Ham.)
5. *Barilius bendelisis* Ham.
6. *Brachydanio rerio* (Ham.)
7. *Rasbora daniconius* (Ham.)*†
8. *Esomus danricus* (Ham.)
9. *Aspidoparia morar* (Ham.)
10. *Amblypharyngodon mola* (Ham.)*
11. *Barbus chagunio* (Ham.)
12. *Barbus chola* (Ham.)*
13. *Barbus sophore* (Ham.)*†
14. *Barbus terio* (Ham.)*†
15. *Barbus ticto* (Ham.)
16. *Catla catla* (Ham.)
17. *Cirrhina reba* (Ham.)*
18. *Garra gotyla* (Gray)
19. *Labeo calbasu* (Ham.)
20. *Labeo gonius* (Ham.)*
21. *Rohtee cotio* (Ham.)*

Family COHITIDAE.

22. *Botia dario* (Ham.)*
23. *Lepidocephalichthys guntea* (Ham.)
24. *Nemachilus zonatus* (McClell.)

Family BAGRIDAE.

25. *Mystus cavasius* (Ham.)*

Family AMBLYCEPIDAE.

26. *Amblyceps mangois* (Ham.)

Family SISORIDAE.

27. *Laguvia ribeiroi* Hora.
28. *Gagata cenia* (Ham.)

Family OPHICEPHALIDAE.

29. *Ophicephalus gachua* Ham.

Family AMBASSIDAE.

30. *Ambassis baculis* (Ham.)*†
31. *Ambassis nama* (Ham.)*
32. *Ambassis ranga* (Ham.)*

Family NANDIDAE.

33. *Nandus nandus* (Ham.)

Family GOBIIDAE.

34. *Glossogobius giuris* (Ham.)*†

An asterisk (*) denotes that the species was collected from the Ganges at Sakrigali Ghat. An asterisk (*) and a dagger (†) denote that the species was collected in the Ganges as also in the hills. Specific names without any mark denote that the species were collected from the Rajmahal Hills only.

[1] Wadia, D. N.—*Quart. Journ. Geol. Mining and Metallurgical Soc. India*, IV, p. 96 (1932).

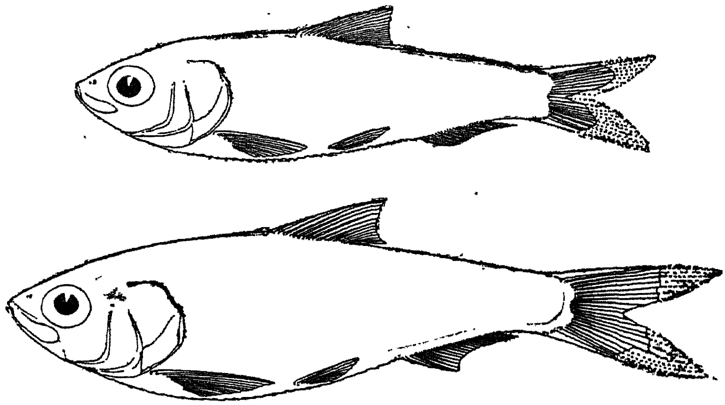
## SYSTEMATIC ACCOUNT.

### **Gadusia chapra** (Hamilton).

1917. *Gadusia chapra*, Regan, *Ann. Mag. Nat. Hist.*, (8), XIX, p. 307.

31 specimens. Sakrigali Ghat, Santal Parganas. (Purchased from market.)

The specimens of *Gadusia chapra* range in length from 23 mm. to 104 mm. in total length without the caudal. The presence of very young specimens in the collection shows that the species breeds in the river Ganges at least as high up as Sakrigali Ghat. Young specimens



TEXT-FIG. 1.—Two young stages of *Gadusia chapra* (Hamilton), 28 mm. and 34 mm. in length without the caudal respectively. ×2.

of *G. chapra* along with a very large number of young ones of *Hilsa ilishia* were recently obtained from the River Hooghli at Nawabgunge near Calcutta. It seems, therefore, that both the species probably breed throughout their range in the Ganges and its tributary streams.

According to Day (*Fish. India*, p. 640), *G. chapra* occurs in " Fresh waters of rivers and tanks of Sind and throughout India as far south as the Kistna River, but absent from the Malabar coast and Madras ".

### **Mastacembelus armatus** (Lacépède).

1876. *Mastacembelus armatus*, Day, *Fish. India*, p. 340, pl. lxxiii, fig. 3.

1 specimen. Gumāni river at Durgapore, Santal Parganas.
1 specimen. Povayal river along Bario-Banji road, Santal Parganas.

*Mastacembelus armatus* is a widely distributed species; its range extends from China, through Burma, to India and Ceylon.

### **Chela clupeoides** (Bloch).

1878. *Chela clupeoides*, Day, *Fish. India*, p. 602.

17 specimens. Sakrigali Ghat, Santal Parganas. (Purchased from market.)
31 specimens. Morel river at Bario, Santal Parganas. (Purchased.)

According to Day, *Chela clupeoides* is found in " Cutch, Jubbulpore, Mysore, the Deccan, Madras Presidency, and Burma". Its occurrence in the Rajmahal Hills, an intermediate area between South India and Burma, is of unusual interest.

### **Chela phulo** (Hamilton).

1878. *Chela phulo,* Day, *Fish. India,* p. 602, pl. cliii, fig. 1.

1 specimen. Morel river near Bario, Santal Parganas. (Purchased.)

*Chela phulo* is distributed from Assam, through Bengal, Orissa and Central India, to the Deccan as far southwards as the Tamboodra and the Kistna rivers.

### **Barilius bendelisis** Hamilton.

1878. *Barilius bendelisis,* Day, *Fish. India,* p. 590, pl. cxlviii, figs. 7, 8 and 9.

There is a very large number of the young of *Barilius* collected from practically all over the area visited by the party. Though the very young ones are difficult to determine specifically, certain specimens over 2 inches in total length can definitely be referred to *B. bendelisis.* The species is fairly widely distributed in Indian waters.

### **Brachydanio rerio** (Hamilton).

1878. *Danio rerio,* Day, *Fish. India,* p. 597, pl. cli, fig. 4.

*Brachydanio rerio* is represented by a large number of specimens, mostly immature, collected from practically all over the area visited by the party. According to Day, the species is found in " Bengal, as low down the Coromandel coast as Masulipatam ".

### **Rasbora daniconius** (Hamilton).

1878. *Rasbora daniconius,* Day, *Fish. India,* p. 584, pl. cxlvi, fig. 2.

1 specimen. Sakrigali Ghat, Santal Parganas. (Purchased from market.)
1 specimen. Morel river at Bario, Santal Parganas. (Purchased.)

*Rasbora daniconius* is the most widely distributed species of the genus ; it is found throughout India, Burma and Ceylon.

### **Esomus danricus** (Hamilton).

1928. *Esomus danricus,* Hora & Mukerji, *Rec. Ind. Mus.,* XXX, p. 49.

1 specimen. Gumāni river near Dhamni, Santal Parganas.
1 specimen. Povayal river along Bario-Banji road, Santal Parganas.
3 specimens. Stream 2 miles from Kusma, Santal Parganas.
1 specimen. Gumāni river near Kusma, Santal Parganas.

*Esomus danricus* is common in the ponds and ditches of Assam, Bengal, Bihar, Orissa, Central Provinces, United Provinces and the Punjab. It is also found in South India.

### **Aspidoparia morar** (Hamilton).

1878. *Aspidoparia morar,* Day, *Fish. India,* p. 585, pl. cxlvi, fig. 4.

1 specimen. Gumāni river near Kusma, Santal Parganas.

*Aspidoparia morar* is represented in the collection by a small specimen, about 27 mm. in length without the caudal. Day recorded the species from " Sind, Punjab, Continent of India (except the Western coast, and localities south of the Kistna river) also Assam and Burma ".

**Amblypharyngodon mola** (Hamilton).

1878. *Amblypharyngodon mola*, Day, *Fish. India*, p. 555, pl. cxxxv, fig. 4.

1 specimen. Sakrigali Ghat, Santal Parganas. (Purchased from market.)

There is a small specimen of *Amblypharyngodon mola*, about 33 mm. in length without the caudal, in the collection under report. Most of the scales have fallen off and in other respects also the specimen is not in a good condition.

*A. mola* is stated by Day to occur " From Sind throughout India (except the Malabar Coast), Assam and Burma ".

**Barbus chagunio** (Hamilton).

1936. *Barbus chagunio*, Hora & Mukerji, *Rec. Ind. Mus.*, XXXVIII, p. 139.

1 specimen. Gumāni river near Dhamni, Santal Parganas.

*Barbus chagunio* is represented by a young specimen, about 51 mm. in length without the caudal. The species is found throughout northern India from Assam to the Punjab ; it is also known from Orissa.

**Barbus chola** (Hamilton).

1878. *Barbus chola*, Day, *Fish. India*, p. 571, pl. cxlii, fig. 4.

1 specimen. Pool about a mile from Sakrigali Ghat, Santal Parganas.

*Barbus chola* is a widely distributed species of the Indian and Burmese waters ; it is represented in the collection by a single specimen about 48 mm. in total length.

**Barbus sophore** (Hamilton).

1878. *Barbus stigma*, Day, *Fish. India*, p. 579, pl. cxli, fig. 5.
1916. *Barbus sophore*, Chaudhuri, *Mem. Ind. Mus.*, V, p. 436.

2 specimens. Sakrigali Ghat, Santal Parganas. (Purchased from market.)
1 specimen. Stream below Boarijore Inspection Bungalow, Santal Parganas.
6 specimens. Povayal river, Bario-Banji road, Santal Parganas.
1 specimen. Gumāni river near Dhamni, Santal Parganas.

*Barbus sophore* is a very common Indian species ; it is found in fresh and brackish waters of India and Burma.

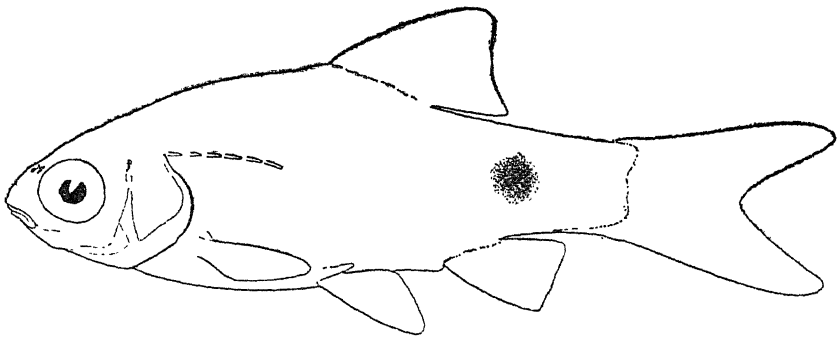
**Barbus terio** (Hamilton).

1878. *Barbus terio*, Day, *Fish. India*, p. 580, pl. cxliv, fig. 3.

1 specimen. Pool near Sakrigali Ghat, Santal Parganas.
10 specimens. Povayal river, Bario-Banji road, Santal Parganas.
1 specimen. Morel river near Bario, Santal Parganas.
3 specimens. Tributary of Morel river west of Bario-Burhait road, Santal Parganas.
3 specimens. Damra river near Simlong, Santal Parganas.
5 specimens. Gumāni river at Dhamni, Santal Parganas.
30 specimens. Gumāni river at Kusma, Santal Parganas.
9 specimens. A stream about 2 miles from Kusma, Santal Parganas.

*Barbus terio* is a small species which is found in northern India from Bengal to the Punjab and also in Orissa. The specimens in the

collection are very young, the largest being about 30 mm. in total length. The most characteristic feature of the species is the presence of a fairly large black blotch in the middle of the side over the anal fin. In the



TEXT-FIG. 2.—A young specimen of *Barbus terio* (Hamilton), showing the position and extent of the caudal spot. ×4.

young specimens under report there are no other colour markings except that the edges of the scales are provided with a number of fine black dots.

### **Barbus ticto** (Hamilton).

1938. *Barbus ticto*, Hora & Misra, *Journ. Bombay Nat. Hist. Soc.*, XL, p. 28.

5 specimens. Gumāni river near Dhamni, Santal Parganas.
6 specimens. Povayal river, Bario-Bānji road, Santal Parganas.

The specimens of *Barbus ticto* exhibit the same sexual characters with regard to colouration, etc., which were observed in the case of the Deolali examples (*vide* reference above). The species is distributed throughout India and Ceylon.

### **Catla catla** (Hamilton).

1878. *Catla Buchanani*, Day, *Fish. India*, p. 553, pl. cxxxiv, fig. 5.

1 specimen. Morel river near Bario, Santal Parganas. (Purchased.)

*Catla catla* is represented in the collection by one young specimen. The range of the species extends from Burma through Assam, Bengal to all parts of India above the Kistna river. It has, however, been recently introduced in the Cauvery river.

### **Cirrhina reba** (Hamilton).

1878. *Cirrhina reba*, Day, *Fish. India*, p. 549, pl. cxxx, fig. 3.

2 specimens. Sakrigali Ghat, Santal Parganas. (Purchased from market.)

*Cirrhina reba* is found throughout India.

**Garra gotyla** (Gray).

1921. *Garra gotyla*, Hora, *Rec. Ind. Mus.*, XXII, p. 653.

34 specimens. Gumāni river near Dhamni, Santal Parganas.

Only recently[1] it was pointed out by me that the young specimens of *Garra*, with a median proboscis on the snout, which I had referred to *G. lamta*, in reality belonged to *G. gotyla*; this extended the range of the latter species to the Vindhyas and the Satpuras. The common occurrence of the species in the Rajmahal Hills fully confirms the view that the Satpura trend may have once served as a highway for the migration of the Himalayan forms to the Western Ghats and thence to the hills of the Peninsular India and Ceylon.

*Garra gotyla* is known from the Chindwin and the Irrawadi drainage systems, and from along the base of the Himalayas. It has now been recorded from several places in the Vindhyan Range.

The largest specimen in the collection is about 75 mm. in length without the caudal. The proboscis is fairly well marked in all the examples.

**Labeo calbasu** (Hamilton).

1878. *Labeo calbasu*, Day, *Fish. India*, p. 536, pl. cxxvi, fig. 4.

1 specimen. Sakrigali Ghat, Santal Parganas. (Purchased from market.)

*Labeo calbasu* is a widely distributed fish of the Indian and Burmese waters; its range does not extend to the south of the Kistna river.

**Labeo gonius** (Hamilton).

1878. *Labeo gonius*, Day, *Fish. India*, p. 537, pl. cxxvii, fig. 1.

5 specimens. Sakrigali Ghat, Santal Parganas. (Purchased from market.)

*Labeo* gonius is found in Burma and throughout northern India as low as the Kistna river.

**Rohtee cotio** (Hamilton).

1878. *Rohtee cotio*, Day, *Fish. India*, p. 587, pl. cli, fig. 1.

39 specimens. Sakrigali Ghat, Santal Parganas. (Purchased from market.)

The specimens of *Rohtee cotio* range in length from 31 mm. to 70 mm. without the caudal and are referrable to the typical form of the species. This is the most widely distributed species of the genus; its range extends from southern China through Burma to India. According to Day, it is not found along the Malabar Coast and in the Peninsula of India south of the Kistna river.

**Botia dario** (Hamilton).

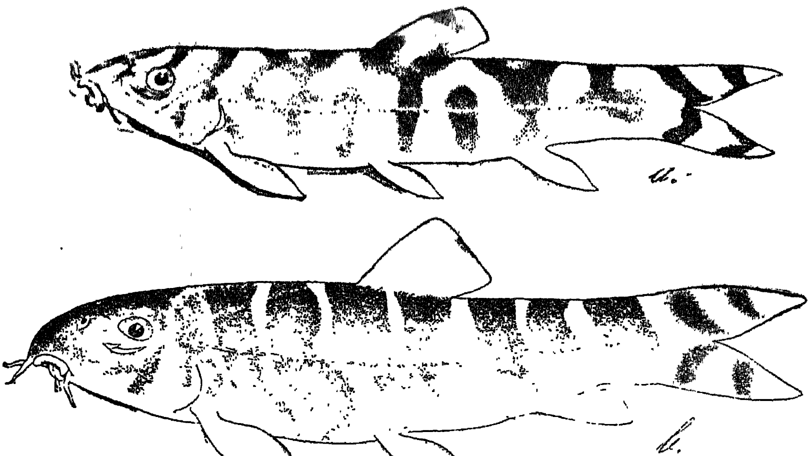
1932. *Botia dario*, Hora, *Rec. Ind. Mus.*, XXXIV, p. 573.

3 specimens. Morel river at Barhait, Santal parganas.

The three specimens of *Botia dario* are 52 mm., 74 mm. and 78 mm. in total length respectively. In the two larger specimens the colour

[1] Hora, S. L.—*Rec. Ind. Mus.*, XXXIX, pp. 347-348 (1937).

bands encircle the entire body; some of them are split into two bands on the ventral surface. In the case of the smaller specimen the bands




TEXT-FIG. 3.—Two specimens of *Botia dario* (Hamilton), showing variation in colouration at different stages of growth. *a.* $\times 1\frac{3}{5}$; *b.* $\times 1\frac{1}{5}$.

on the back enclose small spaces of ground colour which may be saddle-shaped. Some of the markings on the dorsal surface are not continuous with those on the sides. The caudal fin is marked with two bands. The colouration of this young specimen is, therefore, different from Hamilton's *geto*, which is regarded as a juvenile form of *B. dario*.

*Botia dario* has hitherto been known from Assam, and from along the Himalayan foot-hills in Bengal, Bihar and the United Provinces. It is here recorded for the first time from a region to the west of the Ganges.

### **Lepidocephalichthys guntea** (Hamilton).

1878. *Lepidocephalichthys guntea*, Day, *Fish. India*, p. 609, pl. clv, fig. 4; pl. clvi, fig. 12.

7 specimens. Stream below Motijharna, Santal Parganas.
4 specimens. Morel river near Bario, Santal Parganas.
2 specimens. Stream below Boarijore Inspection Bungalow, Santal Parganas.
4 specimens. Pövayal River, Bario-Banji road, Santal Parganas.
1 specimen. Dighi river, Bario-Banji road, Santal Parganas.
1 specimen. Bhanji river at Bhanji, Santal Parganas.
3 specimens. Damra river near Simlong, Santal Parganas.
9 specimens. Gumāni river near Dhamni, Santal Parganas.
3 specimens. Gumāni river near Kusma, Santal Parganas.
1 specimen. Kusmajharna (spring) at Kusma, Santal Parganas.

*Lepidocephalichthys guntea* is found throughout India, except Mysore, Malabar Coast and to the south of the Kistna river.

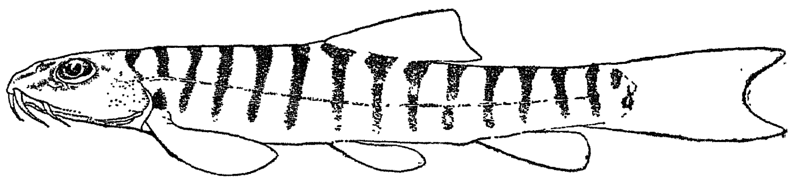
The specimens were collected from sandy or muddy places where the fish lay buried with the head protruding above the substratum.

**Nemachilus zonatus** (McClelland).

1878. *Nemachilus zonatus*, Day, *Fish. India*, p. 618, pl. clvi, fig. 2.

3 specimens. Gumāni river near Dhamni, Santal Parganas.

*Nemachilus zonatus* was described by McClelland from Upper Assam where it was found living in ponds, but Day recorded it from " Throughout the Jumna and Ganges rivers and their affluents, Bheer Bhoom, Assam and Orissa ".



TEXT-FIG. 4.—Lateral view of a male specimen of *Nemachilus zonatus* (McClelland) to show the characteristic colouration of the species. ×2.

The specimens from the Rajmahal Hills were collected from a sandy substratum and agree closely with Day's description of the species. On account of its very characteristic colouration, *N. zonathus* can be distinguished readily from all the other Indian species of the genus. The largest specimen in the collection is about 44 mm. in total length.

**Mystus cavasius** (Hamilton).

1877. *Macrones cavasius*, Day, *Fish. India*, p. 447, pl. c, fig. 1.

6 specimens. Sakrigali Ghat, Santal Parganas. (Purchased from market.)

*Mystus cavasius* is a very common Indian fish and is found in Burma also.

**Amblyceps mangois** (Hamilton).

1933. *Amblyceps mangois*, Hora, *Rec. Ind. Mus.*, XXXV, pp. 607-621.

15 specimens. Small pools at sides of Gumāni river near Dhamni Santal Parganas.
1 specimen. Morel river near Bario, Santal Parganas.
1 specimen. Damra river near Simlong, Santal Parganas.
1 specimen. Gumāni river at Kusma, Santal Parganas.

Only young specimens of *Amblyceps mangois* were collected from the Gumāni river and some of its tributary streams; the largest specimen is about 63 mm. in total length. The species, as a rule, lives at the bases of hills in shallow running streams among gravel and pebble, but in the dry season it is confined to small pools into which such streams are usually cut up.

The specimens from the Rajmahal Hills show precisely the same variations with regard to the depth of the body, the form of the caudal fin, etc., which had previously been observed by me in the examples collected in the Tista Valley.

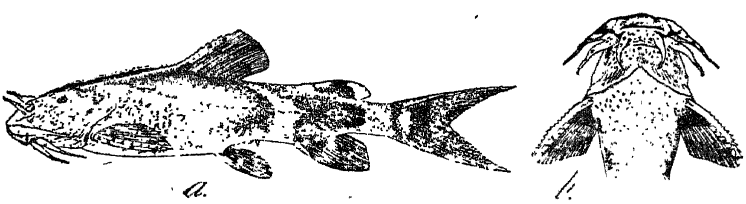
*Amblyceps mangois* has hitherto been known from Siam (Bua Yai, Chantabun; Pak Chong, Nakhon Rachasima; Nakhon Srithamarat and Maenam Canthaburi), North Burma (Putao Plains and Mali Hka river, Myitkyina District), Assam (Khasi, Abor and Naga Hills), Eastern

Himalayas (Siliguri, Sevoke and rivers of Terai and Duars) and Western Himalayas (Gazipore and Kangra Valley); its occurrence in the Rajmahal Hills to the west of the Ganges is of special interest as it shows that the Assam Hills and the Rajmahal Hills must have been continuous at not a very remote period of earth's history.

### **Laguvia ribeiroi** Hora.

1921. *Laguvia ribeiroi*, Hora, *Rec. Ind. Mus.*, XXII, p. 741, pl. xxix, fig. 3.
2 specimens. Morel river near Bario, Santal Parganas.

*Laguvia ribeiroi* was described from a single female specimen collected in the Khoila river, a tributary of the Tista river, and was distinguished from the genotype—*L. shawi* Hora, also known from the Tista river—by the position of the nostrils and the ventrals, and by the nature of the dorsal spine and of the chest region. Since then my colleagues and I have collected hundreds of specimens of *L. shawi* from the Sevoke and the Mahanadi rivers at the base of the Darjeeling Himalayas, and have found a faintly developed adhesive apparatus on the chest of all of them. The position of the nostrils with reference to the tip of the snout and the anterior margin of the eye and also of the ventrals



TEXT-FIG. 5.—*Laguvia ribeiroi* Hora.
*a*. Lateral view. ×2; *b*. Ventral surface of head and anterior part of body. ×2.

with reference to the tip of the snout and the base of the caudal fin have been found to be variable characters. The two species can still be distinguished readily by the nature of the dorsal spine which is strongly serrated anteriorly in *L. ribeiroi* and is smooth in *L. shawi*. In the former the eggs are very large as compared with those of the latter.

The two specimens of *L. ribeiroi* collected in the Rajmahal Hills are about 29 mm. in total length. The colour pattern is bright and dense. The head and body are thickly covered with prominent tubercles on their dorsal and lateral surfaces. The tubercles were at first associated with the sex of the specimens, but a study of a large series of specimens of *L. shawi* showed that these structures are sometimes equally well developed in both the sexes.

*Laguvia* was proposed for the two Tista river species referred to above. A third species *Pimelodus asperns* McClelland[1] was referred to this genus; it was described by McClelland from Chusan in China, but later recorded by Chaudhuri[2] from Upper Burma. The occurrence of *Laguvia* in the Rajmahal Hills is of special interest as it shows the

[1] McClelland, J.—*Calcutta, Journ. Nat. Hist.*, IV, p. 404, pl. xxiv, fig. 2 (1844).
[2] Chaudhuri, B. L.—*Rec. Ind. Mus.*, XVI, p. 276, pl. xxii, fig. 2 (1919).

probable route of dispersal of some of the Far Eastern types of fish that are now found in the extreme south of the Peninsula.

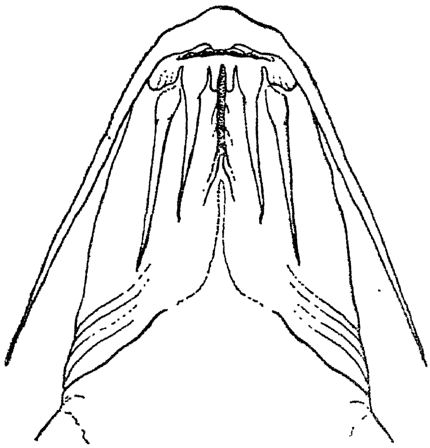
### **Gagata cenia** (Hamilton).

1877. *Gagata cenia*, Day, *Fish. India*, p. 492, pl. cxv, figs. 4 and 5.

2 specimens. Morel river at Barhait, Santal Parganas.

According to Day, *Gagata cenia* is distributed in the "Rivers of Bengal and Orissa, the Jumna, Ganges, and Indus, also Burma".

Two young specimens of the species were collected by the party from the Morel river at Barhait.



TEXT-FIG. 6.—Ventral surface of head of *Gagata cenia* (Hamilton) to show the positions of the 3 pairs of mandibular barbels. ×4.

Besides the two mandibular pairs of barbels with stiff bases there is also a third pair. These are situated in the mid-ventral position between the bases of the inner mandibular barbels and are fleshy, and finger-like. All the three pairs of barbels lie in grooves, especially near their bases, so the median small pair is liable to be overlooked.

### **Ophicephalus gachua** Hamilton.

1922. *Ophiocephalus gachua*, Weber & de Beaufort, *Fish. Indo-Austral. Archipel.* IV, p. 321.

1 specimen. Tributary of Morel river west of Bario, Santal Parganas.
2 specimens. Gumāni river near Dhamni, Santal Parganas.
3 specimens. Povayal river along Bario-Banji road, Santal Parganas.

*Ophicephalus gachua* is one of the most widely distributed species of the Oriental Region.

### **Ambassis baculis** (Hamilton).

1875. *Ambassis baculis*, Day, *Fish. India*, p. 51, pl. xv, fig. 1.

1 specimen. Pool about a mile from Sakrigali Ghat, Santal Parganas.
1 specimen. River Morel at Barhait, Santal Parganas.

According to Day, *Ambassis baculis* is found in Burma and northern India, from Bengal to the Punjab including Orissa.

### **Ambassis nama** (Hamilton).

1875. *Ambassis nama,* Day, *Fish. India,* p. 50, pl. xiv, fig. 5.
9 specimens. Sakrigali Ghat, Santal Parganas.

*Ambassis nama* is a small species ; it is found throughout India and Burma.

### **Ambassis ranga** (Hamilton).

1875. *Ambassis ranga,* Day, *Fish. India,* p. 51, pl. xiv, fig. 6.
2 specimens. Sakrigali Ghat, Santal Parganas. (Purchased from market.)

*Ambassis ranga* is distributed throughout India and Burma.

### **Nandus nandus** (Hamilton).

1875. *Nandus marmoratus,* Day, *Fish. India,* p. 129, pl. xxxii, fig. 1.
2 specimens. Tank at Durgapore, Santal Parganas.

*Nandus nandus* is represented by two specimens in the collection it is found throughout India and Burma in fresh and brackish waters.

### **Glossogobius giuris** (Hamilton).

1876. *Gobius giuris,* Day, *Fish. India,* p. 294, pl. lxv, fig. 1.
3 specimens. Sakrigali Ghat, Santal Parganas. (Purchased from market.)
1 specimen. Gumāni river at Barhait, Santal Parganas.
3 specimens. Gumāni river near Kusma, Santal Parganas.
1 specimen. Gumāni river near Dhamni, Santal Parganas.

*Glossobogius giuris* is a very widely distributed species and occurs in fresh and brackish waters, but according to Day, a variety of it is entirely confined to the sea and estuaries both along the coasts of India, and in the Andamans.

To A. G. K. Menon

*With the Author's compliments.*

Menon

# ON SOME FOSSIL FISH-SCALES FROM THE INTER-TRAPPEAN BEDS AT DEOTHAN AND KHERI, CENTRAL PROVINCES.

BY

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**(With Plates 17 and 18.)**

[From the *Records of the Geological Survey of India*, Vol. 73, Pt. 2, pp. 267-294, (1938).]

# ON SOME FOSSIL FISH-SCALES FROM THE INTER-TRAPPEAN BEDS AT DEOTHAN AND KHERI, CENTRAL PROVINCES, BY SUNDER LAL HORA, D.Sc., F.R.S.E., F.N.I., *Assistant Superintendent, Zoological Survey of India, Calcutta.* (With Plates 17 and 18.)*

## CONTENTS.



## INTRODUCTION.

The fossil fish-scales described below were collected by Mr. H. Crookshank, Superintending Geologist, Geological Survey of India, from the Inter-trappean beds about ¾ mile to the east of Deothan (22° 19′ : 77° 35′) and about ¼ mile to the east of Kheri (22° 22′ : 77° 29′) in the Central Provinces. In his memoir on the 'Geology of the Northern Slopes of the Satpuras between the Morand and the Sher Rivers' (1936, p. 288), he made a reference to my tentative conclusions regarding the identity of some of the fish scales, but later he collected much more varied material. A brief reference was also made to these scales by Crookshank, Sahni, and the writer at the General Discussion on the 'Age of the Deccan Trap' held at the 24th meeting of the Indian Science Congress at Hyderabad in 1937. In the following account the various types of scales are described and their probable relationships elucidated. Opportunity has also been taken to describe some other infra- and inter-

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trappean fish-material in the collection of the Geological Survey of India which had not previously been studied by any specialist.

For the arrangement of the material I have followed Jordan's (1923) system of classification. The evidence furnished by these fish-remains in regard to the age of the beds and the ecological conditions under which the fish lived during that period are discussed at the end of the paper.

It may be indicated at the very outset that the study of fish scales is not sufficiently advanced to enable a specific determination to be made of the various types represented in the material; their broad relationships are, however, quite clear and in some cases it has even been possible to refer them to genera or to very closely allied forms. The great value of the study of fish-scales for purposes of identification and classification is being more and more realised as the science of lepidology makes progress, for, like all other structures of a fish organisation, scales also vary and exhibit different patterns of ornamentation in various groups of fishes. The palæontological value of fish-scales appears to me on a par with that of fossil seeds or teeth. In fact, in most cases it should be more valuable than that of teeth or small fragments of bone.

In determining the fossil material I had to examine the scales of a large number of living forms, and where a similarity with the fossil scales was found, both the present-day and the fossil scales are figured side by side to bring out the full significance and stability of their characters.

Mr. Crookshank has kindly given me the following note concerning the Inter-trappean beds at Deothan and Kheri :—

"These beds vary in lithology from place to place but the chief types at Deothan are black carbonaceous and buff ferruginous shales. Both these varieties are fossiliferous and contain numerous irregular masses of volcanic ash. At Kheri the fossils are found in calcareous shales.

"In both areas the Intertrappean bed is believed to overlie the basal flow of the Deccan trap.

"Other localities in the same region where fossiliferous Intertrappeans were noted are: Khuramba (22° 22′ : 77° 29′), south by east of Patlai (22° 23′ : 77° 33′), and east of Napupura (22° 21′ : 77° 37′). None of these areas has been carefully searched. It is quite likely that a thorough search of them would bring to light further fossil remains of importance.

"As regards Deothan and Kheri the outcrops were carefully searched, but no attempt was made to quarry the fossiliferous shales as it was found that the unweathered material was not fissile and the fossils in it were, therefore, very fragmentary. It is probable that good fossils might be obtained from the fresh material

if it were heated and later quenched, as this would make it split along the planes where the fossils occur.

"As well as the fish remains in these beds there are plant and insect remains, Cypridae, and Gastropods. These fossils have not so far proved to be of much interest."

I am very grateful to Mr. Crookshank for the opportunity of examining this interesting material and for his valuable criticism and helpful suggestions.

The whole of the material dealt with in this paper is preserved in the collection of the Geological Survey of India.

## SYSTEMATIC DESCRIPTION.

### Superorder TELEOSTEI.

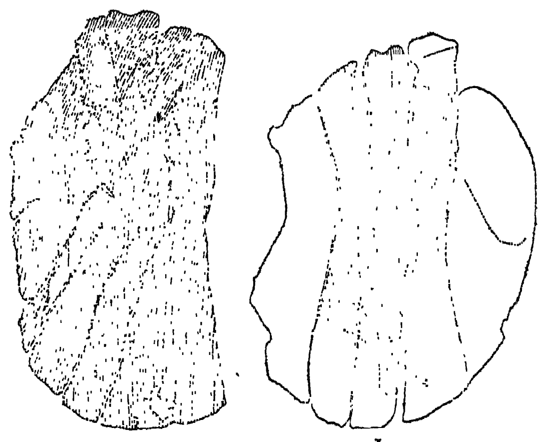
### Order ISOSPONDYLI.

### Suborder CLUPEOIDEI.

### Family *CLUPEIDAE*.

(Plate 17, fig. 3; plate 18, figs. 8, 9 and 10; text-figs. 1 and 2.)

*Material.*—Specimens with transverse radii widely interrupted in the middle, Nos. K32/154, K32/156, K32/159, K32/162, K40/291, K40/292, K40/293, K40/294 (from Deothan); specimens with transverse radii complete, Nos. K32/162, K54/293 (from Deothan).



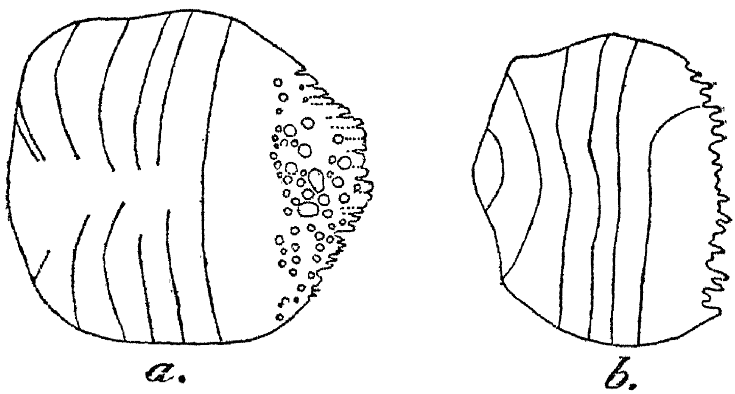
*a.* *b.*

TEXT-FIG. 1.—Two types of fossil Clupeoid scales.

*a.* A scale (K32/159) with transverse radii widely interrupted. $\times 18\frac{1}{2}$; *b.* A scale (G 152) with transverse radii complete. $\times$ *ca* 11.

There are a large number of small, fragmentary Clupeoid scales in the collection, but there is not a single complete specimen.

Two types of scales can be readily distinguished; (i) those in which the transverse radii are widely interrupted in the middle (Plate 17, fig. 3; text-fig. 1*a*) and (ii) those in which the transverse radii are complete (Plate 18, figs. 8, 9 and 10; text-fig. 1*b*). In both cases the extremely fine circuli are more or less transverse and meet the margins at right angles or somewhat obliquely. Both types of scales are found in the genus *Clupea* Linn. and the nature of the transverse radii is often utilised in distinguishing species of these commercially important fishes, most of which superficially appear to be very much alike. Weber and de Beaufort (1913, pp. 76, 81) have figured similar scales (text-fig. 2), while Cockerell (1913, p. 123) has given a good general description of both kinds.




TEXT-FIG. 2.—Scales of the two living species of *Clupea* Linn. (After Weber and de Beaufort).

*a*. *Clupea* (*Harengula*) *fimbriata* (C. V.). ×6; *b*. *Clupea* (*Harengula*) *moluccensis* Blkr. × 6.

*Remarks*.—The Clupeidae comprise a great variety of marine forms and are found practically all over the world. A number of species, such as the American Shad and the Indian Hilsa, enter the mouths of large rivers at certain seasons and give rise to immense fisheries. Though some representatives of the family have been recorded from the Lower Cretaceous, *Clupea* is, according to Zittel (1932, p. 155), "not certainly known below the Upper Eocene of Monte Bolca, near Verona". In view of the occurrence of the scales of *Clupea* both in the Infra- and Inter-trappean beds, however, this view may have to be revised.

## Suborder OSTEOGLOSSOIDEA.

### Family *OSTEOGLOSSIDAE.*[1]

(Plate 17, figs. 7 and 8; text-figs. 3 and 4.)

*Material.*—Specimen No. K29/631 (two pieces), and two more pieces (from Deothan).

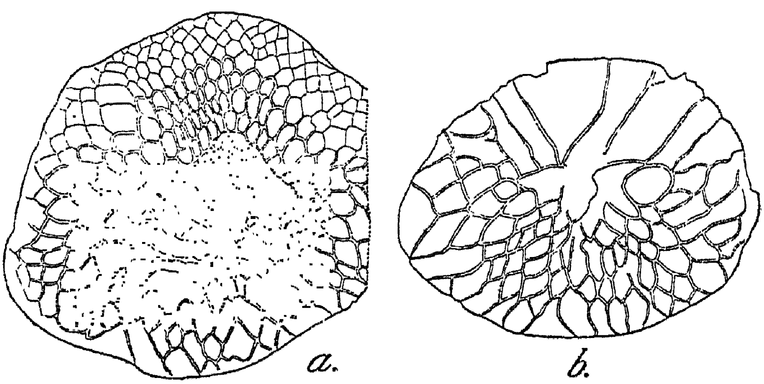
There are altogether four fragments of scales which I refer to the family Osteoglossidae. The scales of this family are large and thick and are composed of mosaic-like pieces. The largest piece in Mr. Crookshank's collection (pl. 17, fig. 7) is about 16 mm. in its greatest length and as this fragment represents more than half of the scale, it may safely be presumed that the diameter of the scale would be about 16 mm. The small mosaic-like pieces are rhomboidal; they are approximately 3 to 4 mm. in length and $1\frac{1}{2}$ to

TEXT-FIG. 3.—A fragment of an Osteoglossid scale (K29/631), genus *Musperia* Sanders. ×7.

[1] Jordan (1923) notes that the Osteoglossidae, the Arapaimidae and the Clupisudidae should perhaps be merged into one family.

2 mm. in width. Some of the pieces at one end are considerably larger. The longer axis of each piece points towards the centre and the periphery. Each piece is marked with very fine circuli which are moniliform throughout. In places where the rough, greyish skin has peeled off, the bony portions exhibit a more or less vermiform sculpture (text-fig. 3).

*Remarks.*—Of all the bony fishes, the Osteoglossidae are unique in regard to their present-day geographical distribution. The living members of the family are found in South America [*Osteoglossum* (Vandelli) Cuvier and *Arapaima* Müller], Africa [*Heterotis*[1] (Ehrenberg) Müller], Siam (*Scleropages* Günther), Indo-Australian Archipelago (*Scleropages*) and Australia (*Scleropages*). These are among the largest freshwater fishes known; the South American *Arapaima* reaches about 15 feet in length. The four living genera have only five species, of which two belong to *Scleropages*. *S. formosus* (Müll. & Schl.) is found in Sumatra, Banka and Borneo and has only recently been recorded from Siam (Smith 1931, p. 177); while the other species—*S. leichhardti* Günther—is mainly known from Queensland, but on the basis of a photo it has also been recorded from New Guinea (Weber & de Beaufort, 1913, p. 14). This remarkable discontinuous distribution of the family is more or less parallel to the distribution of the living Dipnoan fishes, and shows the great antiquity of the Osteoglossidae.




TEXT-FIG. 4.—Fossil Osteoglossid scales from Sumatra. After Sanders. *a.* Scale of *Scleropages* sp.: *b.* Scale of *Musperia radiata* Sanders.

The geological history of the family Osteoglossidae takes it back to the Eocene period (Zittel, 1932, p. 153). *Phareodus* Leidy

[1] Jordan (1919, p. 202) points out that *Clupisudis* Swainson should replace *Heterotis* Ehrenberg.

(=*Dapedoglossus* Cope) is known from the Eocene Green River shales of Wyoming, U. S. A.; *Brychaetus* A. S. Woodw. from London clay and Sheppey and *Scleropages* from the Tertiaries of Sumatra.

In her monograph on the Tertiary freshwater fishes of Middle Sumatra, Sanders (1934) has published photographs of complete scales of *Scleropages* and of her new genus *Musperia.* The structure of the scales of these two genera differs in several respects, some of which are noted below.

In *Scleropages* there is a fairly large nuclear area in the centre (text-fig. 4*a*) which appears to be devoid of smaller pieces and only covered with moniliform striations; the mosaic pieces are relatively small and more or less ovoid or squarish in outline. In *Musperia*, on the other hand, there is no clear nucleus, and the rhomboidal, mosaic pieces are fairly large, especially towards one end of the scale.

A comparison of the text-figures 3 and 4 shows that the fossil scales obtained by Mr. Crookshank correspond with those of *Musperia* in all important respects noted above. In discussing the affinities of her new genus, Sanders has pointed out certain resemblances between *Musperia* and the North American Eocene genus *Phareodus* on the one hand and with the African genus *Heterotis* on the other. It would thus appear tentatively that the original stock which migrated from the north to the south may have consisted of forms like *Musperia*, which is now extinct and whose remains are known from Sumatra on the one hand and Peninsular India on the other. This genus was probably a descendant of *Phareodus* and in its further wanderings along two definite routes it gave rise to *Scleropages* in Siam, the Indo-Australian Archipelago and Australia in the south-east and to the African and South American genera in the south-west. The same two routes of wanderings seem to have been followed by the Dipnoan fishes at an earlier period of the earth's history. It may here be noted that fossil remains of *Ceratodus* Ag. are known from the Kota-Maleri beds of India (*C. hislopianus* Oldham); these beds are in the Godavari valley and are placed in the Upper Gondwana period.

The Osteoglossidae are recorded here from India for the first time; and this is of special significance from a zoogeographical point of view. As indicated above, it points to a possible route of migration by which these large fishes may have spread from India to Africa and later to South America.

Series OSTARIOPHYSI.

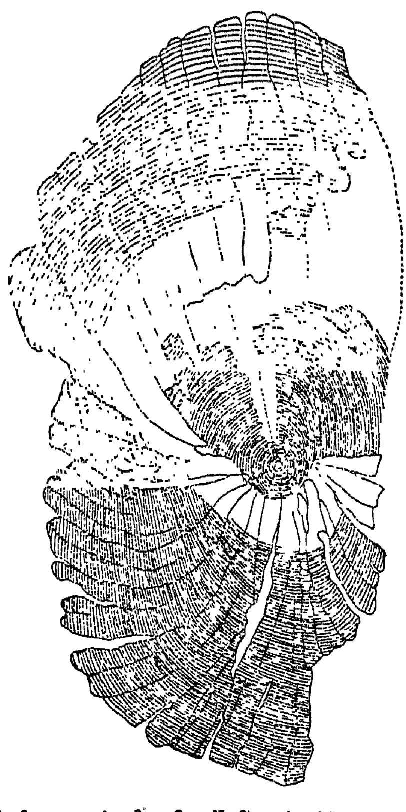
Order EVENTOGNATHI.

Family *CYPRINIDAE*.

(Plate 17, fig. 6; text-fig. 5.)

*Material.*—Specimen No. K32/149 and its counterpart No. K32/150 (from Deothan).

Though there is only one fragment of a Cyprinid scale, its essential structural features are very clear. It seems to have been oval in outline, about one and a half times as long as broad. The nuclear area is small and somewhat eccentric in position. The scale is provided with a large number of radii which are distributed in all directions. The circuli are very fine and compactly arranged.



Text-fig. 5.—A fragment of a fossil Cyprinoid scale (K32/149). ×17.

*Remarks.*—The structure of the scale strongly suggests its very primitive nature and leads to its inclusion in the subfamily Abramidinae. In the main, it corresponds with the scale of *Leuciscus œningensis* Ag. from the Upper Miocene figured by Zittel (1932, p. 157) after Winkler, but its detailed structure and the form are quite different. I have not been able to assign it definitely to any genus, as the scales of most of the living genera have not been so far described.

The Cyprinidae are at present found in great abundance in the fresh waters of the Old World and North America, but are totally absent from South America. In the fossil state they are found from the Lower Eocene to the Pleistocene. Most of the fossil genera are represented by living forms.

### Superorder ACANTHOPTERYGII.

The Acanthopterygii, which include the large group of Perches, are abundantly represented in the existing fauna. In the fossil material collected by Mr. Crookshank there are at least seven types of scales which can be referred to this group of fishes. According to Cockerell (1913, p. 143) a typical Acanthopterygian scale,

> "is more or less quadrate, with the nucleus subapical, the basal circuli fine and transverse, the basal radii strong, spreading out like a fan, and the apical area covered with fine dentiform structures which can be counted in rows obliquely or transversely, and on the margin form a series of fine teeth."

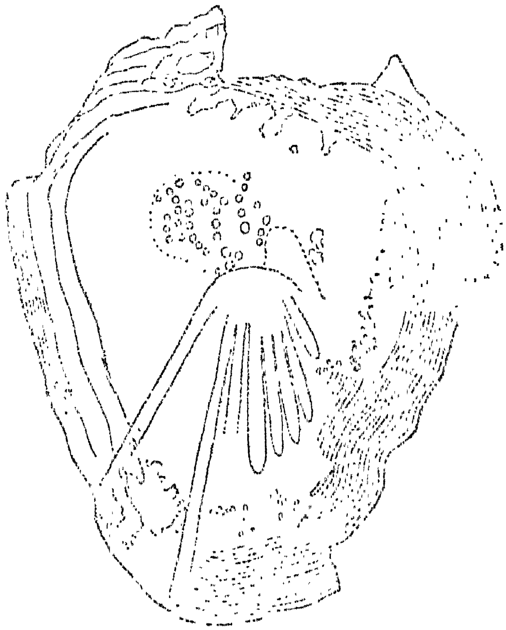
From the above it will be noticed that the scales of *Eoserranus hislopi* described by A. S. Woodward (1908) from the Lameta beds at Dongargaon in the Central Provinces differ from a typical Acanthopterygian scale in the fact that they are cycloid and in them the basal portion, marked with well-developed radii, is much narrower than the apical portion. Woodward's description of the scale (text-fig. 6) is as follows:

> "The scales appear to have been cycloid and rather small. As shown in the type specimen, their exposed sector is ornamented with fine, radiating ridges. Their inner face as shown in impression is marked in the covered portion with radiating furrows."

The *Eoserranus*-type of scale, therefore, seems to represent a primitive stage in the development of an Acanthopterygian scale. According to Cockerell (*loc. cit.*):

> "The toothed or ctenoid feature appears to be derived from the longitudinal apical circuli which become modified and segmented, the terminal segments

especially taking the form of teeth. It is this segmented arrangement which gives the apical area in Acanthopterygians its special character, resembling very much the arrangement of bracts in the heads of some composite flowers."



TEXT-FIG. 6.—A scale of *Eoserranus hislopi* A. S. Woodw. (From the type-specimen, No. 9365 G. S. I.). ×5½.

In my preliminary report to Mr. Crookshank I referred a large scale (pl. 17, fig. 5, text-fig. 8) in his collection to *Eoserranus*, but a careful examination with proper illumination has shown that it is not a cycloid scale. Its general outline is also different from that of an *Eoserranus* scale. In fact, all the Acanthopterygian scales in Mr. Crookshank's collection conform to the general type noted above. There is such a great diversity of Acanthopterygian fishes that it is with great difficulty, and not without hesitation, that I have referred them to any definite genera. Their position in the families noted below, however, appears to be fairly certain.

Order LABYRINTHICI.

Family *POLYACANTHIDAE*.

(Plate 17, fig. 4; text-fig. 7*b*.)

*Material.*—Specimen No. K32/147 (from Deothan).

It is an almost complete scale (text-fig. 7*b*), with part of the apical portion covered by skin. Structurally the scale can be


TEXT-FIG. 7.—A Polyacanthid scale and an allied fossil scale (K32/147).
*a.* *Polyacanthid scale.* ×8; *b.* *Fossil scale allied to that of the Polyacanthidae*, ×8½.

divided into three regions, (i) spiny apical portion; (ii) an area with fine radiating striae between the apical portion and the nucleus; and (iii) the basal area marked with fine circular striae which extend round the nucleus also. There are about a dozen fine, basal radii, of which eight extend almost to the nucleus while the remaining four are shorter. Some of the radii are interrupted in their course. The apical teeth are very small.

*Remarks.*—I have not been able to assign any definite generic position to this scale. While investigating the structure of a large number of freshwater Acanthopterygian scales I found some points of similarity between the fossil scale and that of *Polyacanthus* (K. & v. H.) Cuvier and Valenciennes (text-fig. 7*a*). Cockerell (1913, p. 164) described the scale of the Labyrinthid genus *Anabas* Cuvier and found the same divisions of the scale into three areas. The apical area is beset with linear, spine-like structures, of which the lateral ones are often continuous at the base with the circuli. The apical radii are widely spaced and are about 15 in number.

The scale of *Polyacanthus* appears to be much more specialised than that of *Anabas*; the present-day geographical distribution of the two genera also shows that the latter is certainly a more ancient form. *Anabas* (including the genera *Spirobranchus* Cuvier and *Ctenopoma* Peters) is found in south-eastern Asia and Africa, while *Polyacanthus* is only found in Ceylon, Singapore, Java, Sumatra and Borneo.

So far as I am aware no fossil Labyrinthid remains have hitherto been described.

## Order PERCOMORPHI.

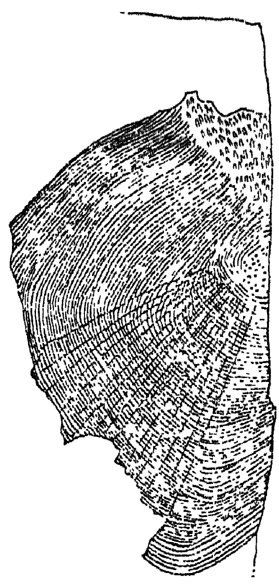
## Series KURTIFORMES.

### Family *SERRANIDAE*.

(Plate 17, fig. 5; text-fig. 8.)

*Material.*—Specimen No. K29/629 (from Deothan).

The scale is represented by an impression of a part of its area. The entire scale must have been about 12 mm. in length and 11 mm.



TEXT FIG. 8.—Impression of a fragment of a Serranid scale (K29/629). ×5.

in width. The nucleus is subapical and, though small in area, is clearly defined. The apical ctenoid area is also well marked, showing several rows of small, clearly defined, sharp spines. The circuli are very fine and compactly arranged. There are about 18 delicate radii, all of which start from near the nucleus and extend towards the periphery for a considerable distance; some even reach the margin.

*Remarks.*—In Cockerell's (1913, p. 143) identification table of the Acanthopterygian scales, the following characters are noted for a Serranid scale:

(i) Basal radii spreading.
(ii) Basal margin not deeply lobed.
(iii) Basal area not beset with linear, spine-like structures.
(iv) Apical margin provided with many sharp and small teeth.

Judged by these features, the fossil scale impression is referrable to the family Serranidae. Though the earliest known Serranid—*Prolates* Priem—dates from the Upper Cretaceous, numerous fossil representatives occur in the Tertiary formations of Europe and North America. I have indicated above (*vide supra*, p. 275) that *Eoserranus* is probably a very primitive representative of the family. The specimen under report possesses a highly specialised structure, so is probably younger than *Eoserranus* in the scale of geological history.

*Incertae Sedis.*

There are two other types of scales in the collection which, though quite distinct from those of the Serranidae, may be described in this place.

TYPE A.

(Plate 18, fig. 5; text-fig. 9.)

*Material.*—Specimen No. K40/286 (from Deothan).

This is a small, almost complete scale. Excluding the apical spines, it is almost as long as broad. The apical teeth seem to form a single row of about 15 teeth. A well formed tooth is about three times as long as broad at the base. The nucleus is well defined and subapical. The scale is provided with a large number of fine

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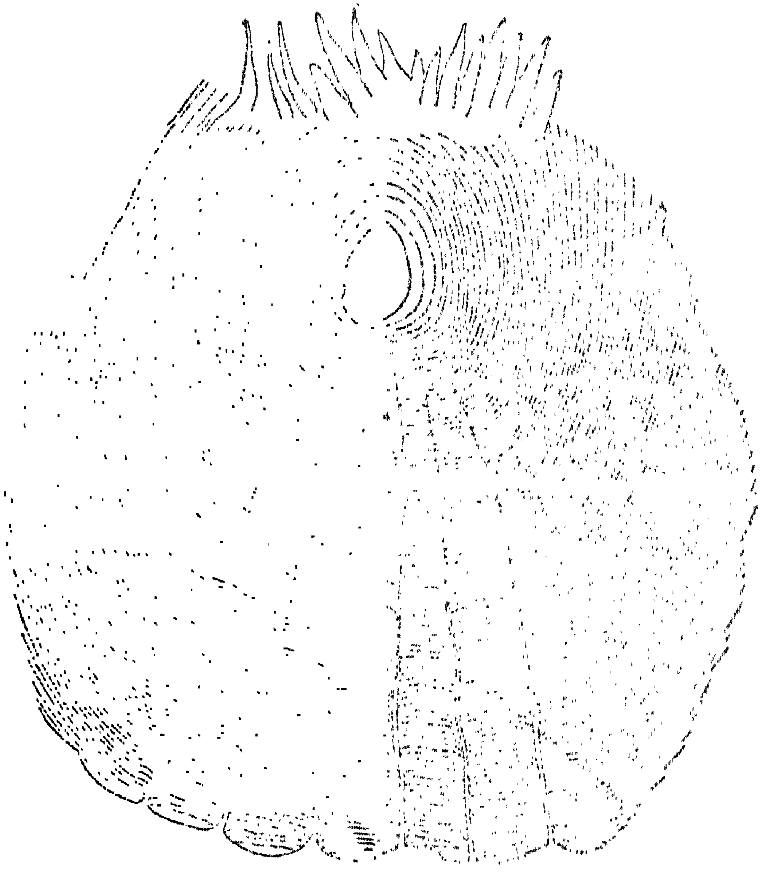
circular striae, a few of which are concentrically arranged round the nucleus. There are only six, well-defined, basal radii which



Text-fig. 9.—A primitive Acanthopterygian fossil scale (K40/286). ×93.

are widely spaced and seem to run almost parallel to one another. The lateral margins of the scale are incomplete but in general outline it appears to have been circular.

*Remarks.*—In the present state of our knowledge of lepidology, I am unable to refer this scale to any Acanthopterygian family From the arrangement of the basal radii and the nature of the apical teeth, this scale appears to be of a somewhat primitive type. It shows a certain amount of resemblance to the scales of the family Mullidae.

TYPE B.

(Plate 18, fig. 6; text-fig. 10.)

*Material.*—Specimen No. K40/283 (from Kheri).

This is only a fragment of the basal portion of a large scale about 9·6 mm. in width. The basal radii are delicate and few in number. The circular striae are very fine and closely set.

TEXT-FIG. 10.—Basal part of a large, fossil, Acanthopterygian scale (K40/283). ×10½.

*Remarks.*—It is very difficult to express an opinion about the relationships of this fragment. It is described and figured here merely because it appears to represent a large scale of a very distinct type, differing from all the other scales in the collection.

Family *NANDIDAE*.[1]

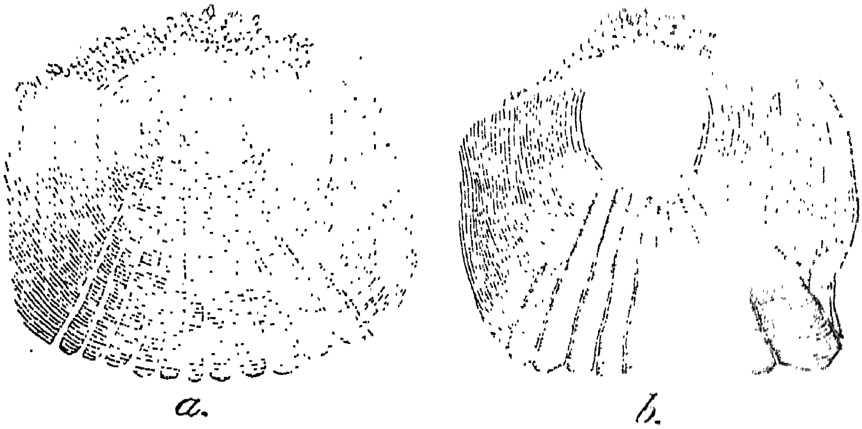
(Plate 17, fig. 2; text-fig. 11.)

*Material.*—Specimens Nos. K29/628, K40/287 (from Deothan); K40/285 (from Kheri).

These are small, subquadrate scales of the Percoid type with a subapical nucleus and strong basal radii. The number of radii varies from scale to scale. The nuclear area is fairly large and the radii, all of which are complete, arise at short intervals from the basal margin of the nucleus. The circuli are fine and closely set. There are several rows of short, blunt spines in the apical region.

[1] In the case of the genera included in the family Nandidae, Jordan (1923, p. 202) remarked that the group may require further division. By certain authorities it is now divided into the family Nandidae for *Nandus* C. V. and the family Pristolepidae for *Pristolepis* Jerdon, *Badis* Bleeker, etc. I have followed the latter arrangement.

*Remarks.*—Superficially these scales appear to resemble those of *Anabas* Cuvier (*vide* Cockerell 1913, p. 164), but the main difference lies in the disposition of the circuli. In *Anabas* "the basal



TEXT-FIG. 11.—A fossil and a present-day Nandid scale.
*a.* Fossil scale (K29/628). ×24; *b.* Scale of *Nandus nandus* (Ham.). ×20.

circuli are dense, the lateral ones rather widely spaced and those at the sides of the apical field strong and very far apart". In the fossil scales they are uniformly distributed. Moreover, the ctenoid patch of *Anabas* is of a totally different nature. In comparing the fossil scales (text-fig. 11 *a*) with those of the living forms I found a great general similarity between them and the scales of *Nandus* Cuvier and Valenciennes (text-fig. 11 *b*). The only difference lies in the fact that in *Nandus* the basal radii are not so strong and some of them may be incomplete.

Though the Nandidae, as restricted at the present day, are found in the Great Sunda Islands, Malay Peninsula, Burma and India, their close allies of the family Polycentridae are found in West Africa and South America.

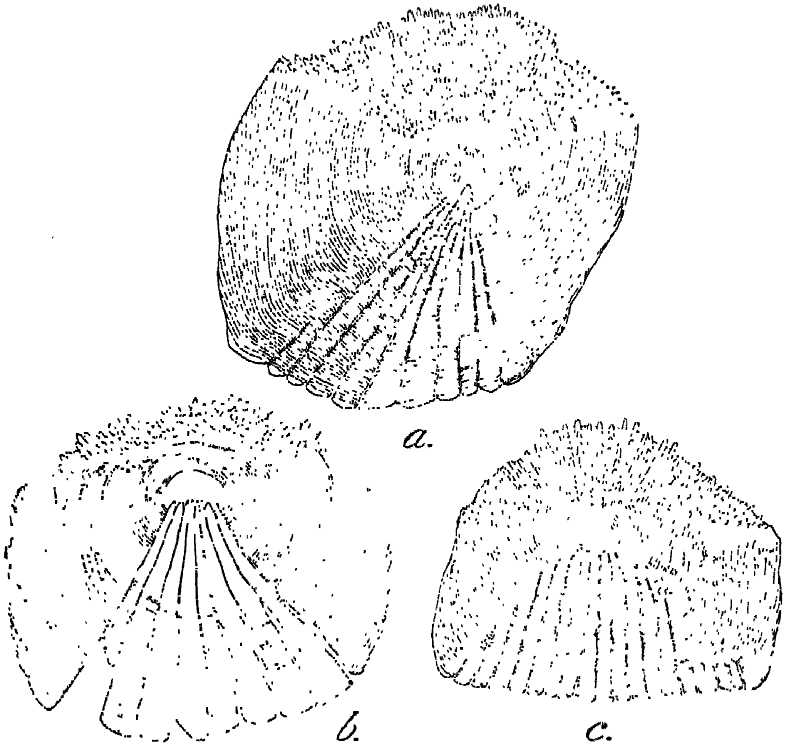
So far as I am aware, no fossil remains of the families Nandidae and Polycentridae have been described so far.

## Family *PRISTOLEPIDAE*.

(Plate 17, fig. 1; text-fig. 12.)

*Material.*—Specimens Nos. K29/629, K32/157, K40/288, K40/289, K40/290, K40/292, K40/295, K40/296 (from Deothan); K31/546, K40/284 (from Kheri).

These small Percoid scales are similar to those of the Nandidae described above. The nuclear area is relatively smaller. The basal




TEXT-FIG. 12.—A fossil and two present-day scales of the family Pristolepidae.
*a.* Scale of *Pristolepis marginatus* Jerdon. $\times 8\frac{1}{2}$; *b.* Fossil scale (K29/629). $\times 17\frac{1}{2}$
*c.* Scale of *Badis badis* (Ham.). $\times 14\frac{1}{2}$.

radii are long and converge in the nucleus. The number of radii varies considerably but they are never less than 8 or more than 15. As a rule, all the radii are complete.

*Remarks.*—There appears to be a general similarity between the fossil scales and those of the genera *Pristolepis* Jerdon and *Badis* Bleeker. This similarity is more marked between the fossil scales and those of *Pristolepis*. From a consideration of the present-day distribution of the two genera, it appears probable that *Pristolepis* is more ancient than *Badis*. The former is found in South India, Burma, Siam, Cochin China and the Sunda Islands, whereas the latter is confined to India and Burma.

So far as I am aware no fossil remains belonging to this family have been described so far.

GEOLOGICAL AGE OF THE INTER-TRAPPEAN BEDS AND SOME OBSERVATIONS ON THE ECOLOGICAL CONDITIONS OF THAT PERIOD.

In a short preliminary article I (1938) have already briefly expressed my views on the probable age of the Deccan trap as evidenced by the fossil fish-remains, but below is given a detailed analysis of the main points at issue.

From a stratigraphical point of view the above results may be summarised as follows :—

| | |
|---|---|
| Family Clupeidae : Genus *Clupea* Linn. | Upper Eocene to Recent. |
| Family Osteoglossidae : Genus *Musperia* Sanders. | Tertiary. |
| Family Cyprinidae : Genus ? Abramadinae | Lower Eocene to Recent. |
| Family Polyacanthidae : Genus ? *Polyacanthus* C. V. | Recent; no fossils previously recorded. |
| Family Serranidae : Genus ? *Serranus* Cuv. | Tertiary to Recent. |
| Family Nandidae : Genus *Nandus* C. V. | Recent; no fossils previously recorded. |
| Family Pristolepidae : Genus *Pristolepis* Jerdon. | Recent; no fossils previously recorded. |

Of the seven families to which Mr. Crookshank's material has been assigned, the first two belong to the Isospondyli, and therefore represent a very primitive stock of the teleostean fishes. Though the Clupeidae go back to the Lower Cretaceous, there is no doubt that the fossil fish scales referred to the family belong to the genus *Clupea*, which, according to Zittel, is not known from below the Upper Eocene. For the determination of the age of the beds, the evidence furnished by the Osteoglossidae is very conclusive, for the fossil remains of this remarkable family are not known from below the Eocene. The Cyprinidae, of which there is only one scale, also go back to the Eocene. The Serranidae are known in the fossil state mainly from the Tertiary formations. So it would seem that these beds cannot possibly be older than the Lower Eocene.

The present-day geographical distribution of the Polyacanthidae, the Nandidae and the Pristolepidae, of which no fossil remains had hitherto been described, throws some light on the upper limit of these beds. The Polyacanthidae and the Nandidae are represented by allied forms in Tropical Africa; in the case of the former the genus *Anabas* Cuvier (family Anabantidae) is common to Africa and south-eastern Asia. Of the two families, the Nandidae would seem to be older, as some allied forms are found in South America.

as well. The family Pristolepidae is confined to south-eastern Asia. These facts of distribution suggest that the Labyrinthid fishes, such as the Anabantidae, Polyacanthidae, etc., and the Nandidae wandered over to Africa when there was still a land connection between India and Africa. The relative localised distribution of the Pristolepidae, on the other hand, suggests that these fishes were probably evolved after the severance of the connection between the two adjacent land masses. The conclusion which may, therefore, be drawn from the fossil records of these families is that the Inter-trappean beds at Deothan and Kheri were probably laid down when the land-bridge between India and Africa had already disappeared.

The only other fossil fish associated with the Deccan traps were reported from the Lameta beds at Dongargaon by A. S. Woodward (1908) who described one new species of each of the following genera: *Eoserranus* A. S. Woodw., *Lepidosteus* Lacépède and *Pycnodus* Ag. From these records he concluded that:

> "Although the Lameta fish-remains are not very satisfactory from the zoological standpoint, they are quite adequate for geological purposes. No true Percoid has hitherto been recognised in a typically Cretaceous formation in any part of the world; the oldest member of the group, as already remarked, being *Prolates* from the Montian of France. *Eoserranus* must therefore be regarded as a Tertiary type of fish. *Lepidosteus* is also typically Tertiary, differing essentially from the numerous Secondary ganoids to which it is related, by its highly specialised vertebrae. It ranges from the Lower Eocene to the Lower Miocene in Europe, and from the Eocene to the present day in North America; but has not previously been found in Asia. While *Eoserranus* and *Lepidosteus* can hardly be older than the beginning of the Tertiary period, the *Pycnodont*, according to the European standard, cannot be later than the close of the Eocene. The age of the Lameta fish-fauna is therefore fixed to be between the Danian Cretaceous and the Upper Eocene."

It is worthy of special remark that Mr. Crookshank did not find in the Inter-trappean beds at Deothan and Kheri any representative of the fauna described by Woodward. Whereas Woodward described two Ganoids and one Teleostean fish, in Mr. Crookshank's material there are Teleostean fishes only. I have now found remains of Clupeoid scales in the material collected by Hislop and other earlier workers from the various Infra and Inter-trappean beds of the Central Provinces. The Ganoids are a very ancient race, but from the beginning of the Cretaceous period their dominant position became more and more displaced by the Teleosteans. By the beginning of the Tertiary period an almost complete change

over of the faunas had taken place and the Ganoids were then represented only by a few forms. It may, however, be noted that *Lepidosteus* and *Amia* continued to flourish for a considerable period, as their fossil remains are recorded for the last time from the Lower Miocene of Europe. They are among the few living genera of the Ganoid fishes. On *a priori* grounds it is clear that Woodward was dealing with a much more primitive fauna than that investigated by the present writer. Woodward's material was collected by Hislop (1861, p. 196), and it seems worth while to enquire into the history of this collection. Hislop made the following observations with regard to the remains of fishes:

"The remains of fishes at Tákli and Pahádsingha consist chiefly of detached scales, some being Ganoidan and other Cycloidan. In the subtrappean yellow limestone of Dongargaum, sixteen miles E. S. E. of Chikni, the impression of a fish was found about 6 inches long and 1·8 inch in the broadest part, which must have been covered with cycloid scales, of a pattern that Sir P. G. Egerton had never seen. The same locality yielded the head of a fish about 9 inches long, with a produced muzzle, armed with sharp sauroid teeth, and rows of smaller ones. A fragment of bone, with 21 of apparently the very same smaller teeth, was dug out from the intertrappean of Tákli. According to Sir Philip, the ichthyolite most nearly allied to this is the *Sphyrænodus* of the London clay. In the Dongargaum limestone there was also embedded a portion of a Ganoid fish, *Lepidotus* or *Lepidosteus* (?) which is 6 inches broad, and when perfect was probably 2 feet long. This seems to be the species which has left so many of its scales in the intertrappean of Takli and Pahádshingha. A separate vertebra of a fish from the subtrappean red clay of Phisdura, 8 miles E. of Chikni, measures ·7 inch in diameter."

In the above passage Hislop refers to three types of beds and enumerates the fossil fish-remains collected from each, but Woodward apparently dealt with only the fish-remains obtained from the Lameta beds at Dongargaon. If, however, the Dongargaon material collected by Hislop is listed with the material from the same beds examined by Woodward there appear to be some inconsistencies. The following table illustrates my point:

| Material collected by Hislop and noted in the passage quoted above. | Specific identification by Woodward. | Material examined by Woodward. |
|---|---|---|
| Impression of a fish, about 6 inches long and 1·8 inch in the broadest part, which must have been covered with cycloid scales. (*Not examined by Woodward.*) | *Eoserranus hislopi* A. S. Woodward. | One fragment of trunk; several specimens showing parts of head, and one showing scale impressions. |

| | | |
|---|---|---|
| Head of a fish about 9 inches long with a produced muzzle, armed with sharp sauroid teeth, and rows of smaller ones. | *Lepidosteus indicus* A. S. Woodward, (figured by Woodward, pl. i, fig. 8). | Skull and a group of head-bones with scales and vertebrae. |
| A portion of a Ganoid fish, *Lepidotus* or *Lepidosteus* (?) which is 6 inches broad. | *Lepidosteus indicus* A. S. Woodward. (Portions figured by Woodward, pl. i, fig. 9, *a-d*). | |
| | *Pycnodus lametae* A. S. Woodward. | One skull. |

It would thus appear that Woodward examined more specimens from Dongargaon than are noted to have been collected by Hislop in the passage quoted above. Presumably at some later date Hislop may have made further collections of fish-remains from the Dongargaon beds.

From the sub-trappean red clay of Phisdura, Hislop obtained a vertebra, about ·7 inch in diameter, which does not appear to have received the attention of any palæontologist so far. The specimen is not present in the collection of the Geological Survey of India, so I am unable to say anything about its systematic position.

From the Inter-trappean of Tákli and Pahársingha Hislop obtained detached Ganoid and cycloid types of scales. Further, a fragment of bone with 21 small teeth, was also obtained from the Inter-trappean beds at Tákli; unfortunately this material has not yet been studied by any specialist.

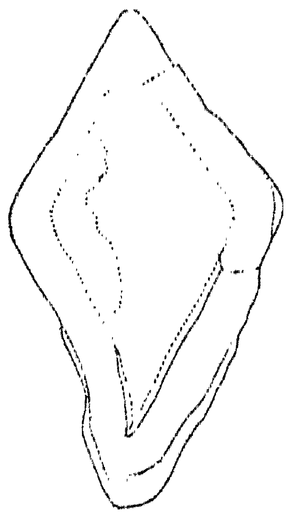
Besides some of the Dongargaon specimens studied by Woodward and now preserved in the collection of the Geological Survey of India (Nos. 9360-68; *vide* Woodward 1908, pl. I, fig. 1-6, 9 *b-d*, 10), there are four other specimens (No. K1/316-319) in the collection of that department which are entered in the register as a donation from Rev. S. Hislop. The following further particulars are also noted against each:—

| | | | |
|---|---|---|---|
| K1/316. | Ganoid scales. | Inter-trappean | Pahársingha, Nagpur, C. P. |
| K1/317. | Cycloid scales. | Inter-trappean[1] | Dongargaon, Nagpur, C. P. |
| K1/318. | Cycloid scales. | Inter-trappean | Pahársingha, Nagpur, C. P. |
| K1/319. | Fish roe. | Inter-trappean | Tákli, Nagpur, C. P. |

[1] Mr. Crookshank informs me that this should be infra-trappean. He wrote to me as follows:—

"As regards the age of the Dongargaon beds we are satisfied that the Inter-trappean in our register should read infra-trappean. All accounts agree that there is only one fossiliferous bed and that infra-trappean. The map shows the same. The disagreement is as to whether this bed should be regarded as infra-trappean of Inter-trappean age or as Lameta."

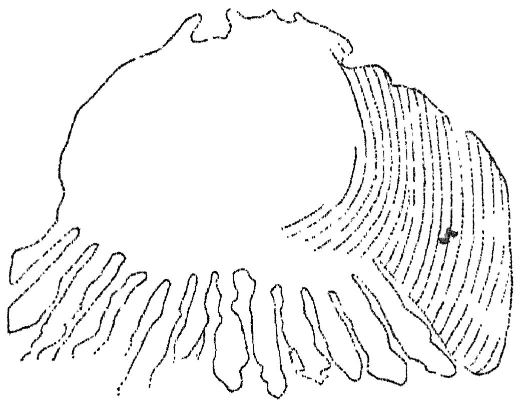
The two Ganoid scales (K1/316; Pl. 18, fig. 2 & 3; text fig. 13) are of small size and rhombic in outline. Except for their size,



TEXT-FIG. 13.—A Ganoid scale (K1/316) from the Inter-trappean bed at Paharsingha. ×10½.

they agree very closely with the scales of *Lepidosteus indicus* Woodw. (Pl. 18, fig. 4; a loose scale from specimen 9366 of the type series). The Inter-trappean (possibly Lameta) cycloid scale from Dongargaon (K1/317; Pl. 18, fig. 10) belongs to the genus *Clupea*, and is of the type in which the transverse radii are complete. This scale corresponds with similar scales described above from the Inter-trappean beds at Deothan and Kheri. It may here be noted that in the collection of the Geological Survey of India there are two specimens of Clupeoid scales with complete transverse radii (G 152, Pl. 18, fig. 8 & 9; text-fig. 1 *b*) collected from the infra-trappean bed at Dhamni, east of Warora, by F. Fedden in September 1874. This record shows that *Clupea* was found during the infra-trappean period also. The second cycloid scale (K1/318, Pl. 18, fig. 7; text-fig. 14) from Pahársingha appears to be a ctenoid scale of the Percoid type in which the apical teeth are not well preserved or are not exposed. In its minute structure, it bears a close resemblance to the scales of the family Nandidae (*vide supra*, p. 281), a family whose close allies are at the present-day found as far apart as south-eastern Asia, Africa and South America, thereby showing its great antiquity. The fourth specimen of a fish roe (K1/319, Pl. 18,

fig. 1), though of considerable interest from the point of view of its excellent state of preservation, is of little value for the determination of the fish to which it may have belonged.



TEXT-FIG. 14.—A Nandid scale (No. K1/318) from the Inter-trappean bed at Paharsingha. ×30.

As to the fish bone from Tákli with 21 small teeth, it may be safe to presume, on Hislop's testimony, that it probably belonged to the Ganoid *Lepidosteus*.

In view of what is stated above it may now be possible to infer the relative ages of the various beds; but it should be borne in mind that the material is not sufficient to come to any definite conclusion.

Mr. Crookshank tells me that doubts have recently been expressed by Matley on Hislop's determination of the age of the Dongargaon beds, and has given me the following note on this point:

"Hislop states definitely that the Dongargaon fish-remains were found in yellow limestone beneath the Trap. Hughes,[1] who subsequently mapped the area, confirms this, and it is clear from his map that the fossil fish in question were found in beds underlying the Trap, and overlying the Gondwanas.

"Matley[2] re-visited the area in 1919. He admitted that the fish beds underlay Trap, but he could not say whether they rested on Trap, or on older rocks, as he had not seen the base of the beds. It is clear, therefore, that he saw nothing in the field inconsistent with the views of Hislop and Hughes. Nevertheless he concluded that the Dongargaon beds were not Lametas, but were of Inter-trappean age.

[1] *Mem. Geol. Surv. Ind.*, XIII, Pt. I, (1877), pp. 89-90.
[2] *Rec. Geol. Surv. Ind.*, LIII, Pt. 2, (1921), pp. 159-162.

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"In making this change he did not rely on the obvious field evidence of the superposition of one set of beds on another. He relied on the lithological dissimilarity of the Dongargaon beds and the Lametas of Jubbulpore, and on the fossil evidence obtained from the Dongargaon beds. These contain fossil fishes said to be early Tertiary, *Bullinus princepii* and a *Melania* similar to those in the Deccan trap Inter-trappeans, and the caudal vertebrae of *Titanosaurus blanfordi* Lydeker, all of which he considers younger than the Lameta fossil remains of Jubbulpore.

"As the Dongargaon beds were clearly infra-trappean, and were at the same time unlike the true Lametas, and seemed to be younger than them, Matley explained the occurrence as a case of infra-trappean beds of Inter-trappean age. While Matley may be right it is legitimate to point out that no other geologist has found infra-trappean beds of Inter-trappean age, that Saurian bones have never been found in *undoubted* Inter-trappean beds, that *Melania* and *Bullinus* have been found elsewhere extending down into the Cretaceous, and that the lithological evidence is of very little importance. On the whole Hislop's and Hughes' views seem more credible than Matley's, the more so as there is probably a big gap between the end of the Gondwana and the beginning of the Deccan trap period, a gap which is quite wide enough to hold fossil faunas differing as widely as those of the Jubbulpore Lametas and the Dongargaon beds.

"Assuming then that Hislop is right the fossil fish from Dongargaon are probably older than those at Deothan and Kheri. If on the other hand Matley is right they should all be of approximately the same age."

It may be noted, however, that Mr. Crookshank's material was collected on the borders of Hoshangabad and Betul, 100 or more miles distant from Dongargaon, and that it is impossible to correlate the two areas exactly as they are separated by a wide area of unfossiliferous Deccan trap.

Without entering into the geological merits of the controversy concerning the age of the beds at Dongargaon, whether infra- or inter-trappean, it is possible to say from a study of the fish-remains enumerated above that the beds at Dongargaon, associated with a relatively primitive fauna of two Ganoids, *Clupea* and one very primitive Serranid, must be regarded of an earlier age than the Inter-trappean beds at Deothan and Kheri, whence Mr. Crookshank obtained such a great variety of the modern teleostean fish. It is true that Ganoid scales and a piece of bone of the *Lepidosteus*-type have been found in the Inter-trappean beds at Takli and Kateru[1] but the scales are of a relatively much smaller size than those of *L. indicus*, and would thus seem to be of a later period when

[1] Mr. S. R. Narayan Rao discovered the remains of *Lepidosteus* scales from the Inter-trappean bed at Kateru, near Rajamundry, and very kindly allowed me to see and identify the specimen for him. He proposes to publish a separate note on the specimen.

the large deep rivers of the area had presumably been replaced, through the outpouring of lava, by shallow streams.

It may be noted that when large fishes of the type of *Eoserranus*, *Lepidosteus indicus* and *Pycnodus* flourished in the Peninsula (the age of the infra-trappean beds at Dongargaon) the main river of the area may have been like a large deep river, but at the time when the Deothan and Kheri beds were laid down marshy conditions, with lakes of varying sizes in the neighbourhood of the mouth of a large river, had been established. The conditions then were probably similar to those now prevailing in the lower reaches of the Ganges. The presence of a considerable number of Clupeoid scales of fairly large size clearly indicates the deltaic nature of such a river not very far from the beds investigated by Hislop, Fedden, and Crookshank. Clupeoids are mostly marine fishes, but some ascend into large rivers for long distances. The occurrence of the Nandidae, the Pristolepidae, the Polyacanthidae and the Serranidae in the Inter-trappean beds at Deothan and Kheri also indicates the maritime nature of the area, for fishes of these families, even at the present day, are commonly met with in freshwater areas not very far removed from the sea. The typically freshwater Cyprinoids are represented by a single scale of a primitive type, but it will be premature to draw any conclusions from this solitary record, as extensive collections of fish remains, especially of the type dealt with here, have not yet been made.

With regard to the ecological observations made above Mr. Crookshank has very kindly given me the following note from a geological point of view:

"Arguing from the habits of the living fish most closely related to the fossil remains it seems that Deothan and Kheri, where the fossils were found, must have lain on the course of some deep sluggish stream not very far from the sea. The geological evidence on this point is of some interest.

"All geologists who have worked in connection with the Deccan trap have remarked on the extraordinarily low relief of the pre-trappean land surface. Any large river draining this would certainly have been deep and sluggish. The first flows of trap would probably have disturbed such a river but might not have diverted its course greatly. The sediments associated with the fish scales are fine calcareous muds such as one would expect to find in ox-bows or other deep pools associated with large rivers of the present day. The only unusual feature is the presence of volcanic lapilli. Doubtless these were introduced by a shower of volcanic ash immediately preceding the lava flow which buried the pool.

"It is idle to pretend that the details of the drainage and the coastline of western India in pre-trappean times are known, but it is supposed that a great river whose valley is now hidden by the Deccan trap must have flowed westward towards



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the Arabian sea somewhere south of the present Narbadda valley. The exact location of such a river is not known, but its upper reaches are probably represented by the Gondwana valleys of the Satpuras and of Wardha district. The lower reaches are entirely hidden by the Deccan trap.

"Marine sedimentaries of late Cretaceous age extend up the Narbadda valley to within 100 miles of Deothan. Nummulitic limestones of Parisian age occur 150 miles further west along the margin of the trap in Broach and Surat. The Deothan fish must have lived at some time between the end of the Cretaceous and the Parisian. It is a reasonable guess, therefore, that there was open sea somewhere between 100 and 250 miles to the west of Deothan in early Deccan trap times.

"The very meagre geological evidence therefore tends to support the conclusions concerning the habitat of the Deothan fossil fishes reached on purely zoological evidence."

In connection with the ecology of the Deothan and Kheri beds attention may be directed to an observation made by Sahni (1934, p. 136) regarding the flora of the Inter-trappean bed at Chhindwara, a place not very far distant from where Crookshank collected his material. In the course of his arguments regarding the Eocene age of these beds he stated:

"One more point seems important although Rode himself does not refer to it. *Nepadites* is not only a genus very characteristic of the eocene period but, unless these palms have changed their mode of life since then, its occurrence in the northern part of the Deccan indicates the existence of an *estuary*, during the early part of the Inter-trappean period in the proximity of Chhindwara. In their valuable memoir on the London Clay flora recently published Reid and Chandler have shown that nearly all the fossil records of *Nipa*-like palms 'lie approximately along the margins of the ancient Nummulitic, or Tethys, sea and its extensions'. So, most probably a north-flowing river debouched into the great Tethys sea or into an arm of that sea, not far to the north of Mr. Rode's home!"

It is thus seen that geological, palaeontological and faunistic evidences all point to the same conclusion, that is, an estuary must have existed in the neighbourhood of the infra- and Inter-trappean beds of the Central Provinces.

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## EXPLANATION OF PLATES.

### PLATE No. 17.

*Inter-trappean Fish Remains.*

Fig. 1.—A Pristolepid scale (K29/629). ×20.

Fig. 2.—A Nandid scale (K29/628). ×20.

Fig. 3.—A fragment of a Clupeoid scale (K32/159). ×15.

Fig. 4.—A Labyrinthid scale (K32/147) allied to *Polyacanthus* C. V. ×7.

Fig. 5.—An impression of a Serranid scale (K29/629). ×3.

Fig. 6.—A fragment of a Cyprinoid scale (K32/149). ×7.

Fig. 7.—A fragment of an Osteoglossid scale (K29/631). ×3.

Fig. 8.—Another fragment of an Osteoglossid scale (K29/631). ×3.

### PLATE 18.

*Inter-trappean Fish Remains.*

Fig. 1.—Fish roe (K1/319) from the Inter-trappean of Takli. ×4.

Fig. 2.—Ganoid scale (K1/316), probably of *Lepidosteus*, from the Inter-trappean of Paharsingha. ×4.

Fig. 3.—Another Ganoid scale from Paharsingha. ×5.

Fig. 4.—A scale of *Lepidosteus indicus* Woodw. (No. 9366). ×4.

Fig. 5.—An Acanthopterygian scale (K40/286), Type A. ×20.

Fig. 6.—Fragment of an Acanthopterygian scale (K40/283), Type B. ×4.

Fig. 7.—A Nandid scale (K1/318) from the Inter-trappean of Paharsingha. ×15.

Fig. 8.—Scale of *Clupea* sp. (G 152) from the infra-trappean at Dhamni. ×7.

Fig. 9.—Impression of a scale of *Clupea* sp. (G 152) from the infra-trappean at Dhamni. ×3.

Fig. 10.—Scale of *Clupea* sp. (K1/317) from the infra-trappean of Dongargaon. ×7.

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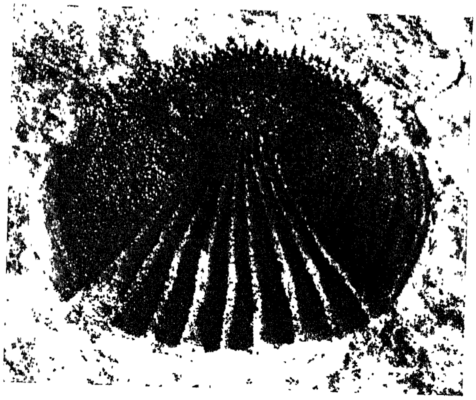

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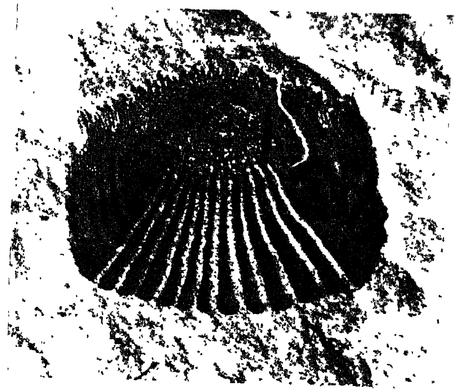

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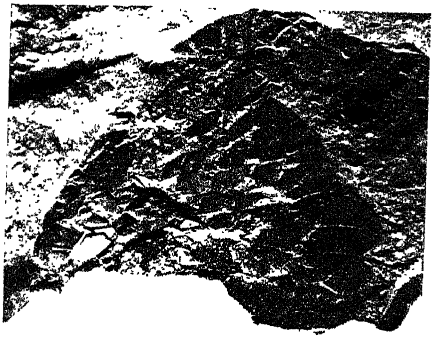
*S. C. Mondul, Photos.*



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*G. S. I., Calcutta.*

INTER-TRAPPEAN FISH REMAINS.

INTER-TRAPPEAN FISH REMAINS.

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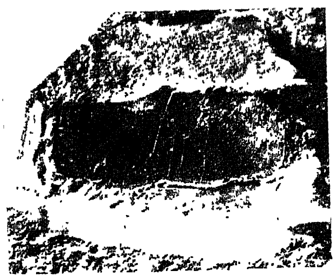

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*S. C. Mondul, Photos.*

*G. S. I., Calcutta.*

INTER-TRAPPEAN FISH REMAINS.

*To*..............................................................

*With the Author's compliments.*

# ON TWO SMALL COLLECTIONS OF FOSSIL FISH-REMAINS FROM BALASORE, ORISSA.

BY

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**(With Plate 13.)**

[ From the *Records of the Geological Survey of India,* Vol. 74, Pt. 2, pp. 199-215, (1939).]

# ON TWO SMALL COLLECTIONS OF FOSSIL FISH-REMAINS FROM BALASORE, ORISSA. BY SUNDER LAL HORA, D.Sc., F.R.S.E., F.N.I., *Assistant Superintendent, Zoological Survey of India, Calcutta.* (With Plate 13.)*

In May 1937, Dr. M. R. Sahni, Palaeontologist, Geological Survey of India, handed over to me a small collection of fossil specimens obtained by Mr. N. H. Cour-Palais, Assistant Engineer, Bengal Nagpur Railway, from a tube well boring between 100 and 200 feet below ground level at Balasore. In sending the material Mr. Cour-Palais had remarked that " similar fossils have been found in several other tube wells here and even at Baripada, 40 miles from the sea, Mayurbhanj State ". Later, in September 1937, Mr. W. D. West, Assistant Director, Geological Survey of India, sent more material of similar fish-remains, which had been presented to the Survey by Mr. J. G. Gilson, Secretary, Balasore Technical School, Balasore. Mr. Gilson obtained this material from " white sand deposit between 125 and 175 feet below ground level in a well at Soro, Balasore District ".

Fossil fish-remains in both the collections are of a very fragmentary nature and comprise teeth of sharks and rays, bits of tail-spines of rays, portions of pectoral and dorsal spines of Cat-fishes and teeth of certain Scombrioid fishes. These remains are, however, fairly well preserved and indicate a Tertiary age of the beds in which they lay entombed.

There is a great variety of shark teeth in the material under report and it has been possible to assign them to *Carchariolamna* gen. nov., *Oxyrhina* Ag., *Scoliodon* M. & H., *Priodon* M. & H., *Hyprion* M. & H. and *Apriodon* Gill. Both the teeth and tail-spines of rays are referred to the family Myliobatidae. The Siluroid remains probably belong to the genus *Arius* Cuv. & Val., but the spines are very fragmentary for any specific determination. Some of the Scombrioid teeth probably belong to the genus *Trichiurus* Linn., while in the case of 2 isolated short, rounded and hollow teeth it has not been possible to determine them even generically, though they show Scombrioid affinities.

* Published with the permission of the Director, Zoological Survey of India.

With the exception of *Carchariolamna*, all the other genera, to which the material has been assigned, are found in a living state at the present day. The new genus, as its name implies, is closely related to *Lamna* Cuvier, a genus ranging from the Upper Cretaceous to the present day, but the teeth, on the characters of which it is based, possess delicately serrated edges. It is thus also related to *Carcharoides* Ameghino, a genus so far known only from the Eocene formations of South America and Australia, but can be readily distinguished from Ameghino's form by its less developed lateral denticles, form of teeth and the nature of their serrated edges. Taking into consideration the known geological history of the various genera represented in the collections, especially of the genus *Hypoprion*, it may be inferred that the boring at Balasore may have traversed the various strata as far down as the Middle Tertiary formations.

Concerning the probable age of the rocks met with in the Balasore borings, Dr. M. R. Sahni has favoured me with the following note dealing with other occurrences of Tertiary rocks in borings, etc., in Mayurbhanj State :—

"At Molia, 2 miles south of Baripada, are exposed in the bed of the Barabalang river, yellowish and yellowish-brown limestones, very rich in remains of *Ostrea*. Dr. Pilgrim who examined a few of them considered them related to certain Tertiary forms, namely, *Ostrea multicostata* Deshayes, from the upper part of the Eocene of the Paris basin, and *O. torresi* Phillipi, from the *Magellania* beds of Patagonia, which are probably Oligocene in age. It was further thought that these specimens are related to an undescribed species of *Ostrea* found in the upper Nari beds of Baluchistan, which are probably Oligocene in age. " The age of these beds is therefore Eocene or Oligocene on this evidence (P. N. Bose, *Rec. Geol. Surv. Ind.*, XXXI, Pt. 3, p. 167).

"In the Tertiary deposits at Baripada, a boring was put down in a well at the traveller's bungalow and was carried down to a depth of 163 ft. (including 40 ft., the depth of the well). "At a depth of 123 ft. below the surface occur limestones with fragment of an *Ostrea* (?).

"Unfortunately, the fossils yielded by the boring are generally indeterminable. The limestone at 142 ft. from the surface is crowded with *Amphistegina*. Dr. Pilgrim observes: 'Although it is true that *Amphistegina* was very much more abundant in the Miocene, still it is found in the seas of today, most commonly up to a depth of 30 fathoms. But added to the testimony of the *Ostrea* (*Rec. Geol. Surv. India,* XXXI, Pt. 3, p. 167), it strengthens the probability that we are dealing with a marine deposit which is at all events as old as Miocene ' (G. Pilgrim in P. N. Bose, *Rec. Geol. Surv. Ind.*, XXXIV, Pt. 1, p. 43).

"According to this evidence, then, the beds were thought to be Miocene or older. " But Dr. Tipper who re-examined these fossils has thrown doubt upon their identification. " He considers that the specimens collected by Mr. P. N. Bose

and identified by Dr. Pilgrim are not *Amphistegina* but *Rotalia*. This *Rotalia* is related to the recent *R. orbicularis* d'Orb from the Arabian Sea and is perhaps allied to *R. beccarii*, Linn.

"Now the genus *Rotalia* is known from the Jurassic to the present day, hence it is impossible to draw any conclusion with regard to the age of the deposit (G. H. Tipper, *Rec. Geol. Surv. Ind.*, XXXIV, p. 135).

"The evidence on the whole indicates that the beds are probably not so old as they were first thought to be.

"Certain specimens of *Ostrea* found in the yellowish and yellowish-brown limestones at Molia, were examined by Mr. Eames and identified as *Ostrea* (*Crassostea*) *gajensis*. This species is recorded by Vredenburg from the upper Gaj of N. W. India, and also from Burma.

"Specimens of this species from the Burma Tertiaries are all of Lower Miocene age.

"It, therefore, appears very probable that these Baripada limestones are of Gaj (Lower Miocene) age (F. E. Eames, *Rec. Geol. Surv. Ind.*, LXXI, Pt. 2, p. 150).

"The writer (M. R. Sahni, *Rec. Geol. Surv. Ind.*, LXVIII, Pt. 4, p. 419) examined a few lamellibranch specimens collected (not *in situ*) from the foreshore at Puri and compared them with the Miocene form of *Paphia gregaria* (Partsch), thus postulating the probable underground occurrence of Miocene rocks near Puri. The matrix infilling these specimens is identical to that in the Baripada boring, previously mentioned and the Balasore boring.

"In conclusion I may say that, considering the fresh appearance of the Balasore fossils and the greyish clay matrix which appear to be identical with that found in the Baripada boring (*vide ante*), the rocks met with in the Balasore boring are not older than Miocene and are probably younger."

The entire material is preserved in the collection of the Geological Survey of India (Mr. Cour-Palais's specimens are numbered K 40/275—K 40/281, and G. S. I. Types 16646-16651, and Mr. Gilson's K 40/311—K 40/316). Besides the specimens actually reported upon in this article, there are few small bits which I have left indetermined. Owing to the fragmentary nature of the material and a large number of fossil sharks described on insufficient data, I have not attempted a specific determination of the majority of the fossil teeth. In some cases, it has not been possible even to assign a generic position.

I am grateful to Dr. A. M. Heron, Director, Geological Survey of India, through whose kindness I have been afforded an opportunity to report on the Balasore fossil fish-remains. My sincere thanks are also due to Dr. M. R. Sahni for his valuable note on the probable age of the rocks, and for his suggestions. To Dr. E. I. White I am greatly indebted for his helpful criticism and suggestions in connection with some of my determinations.

## Class ELASMOBRANCHII.

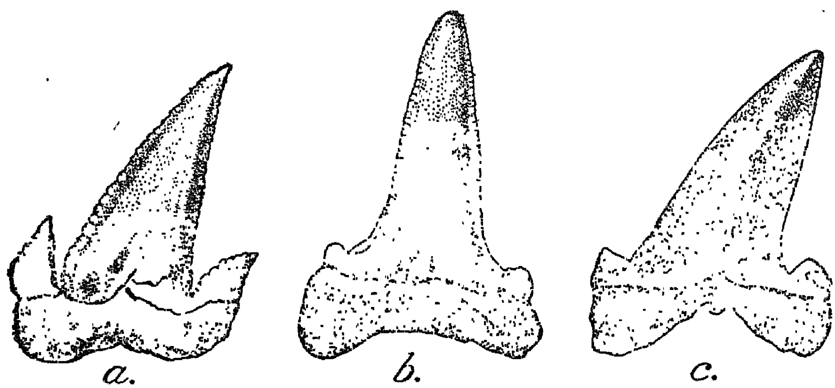
## Sub-Class SELACHII.

## Order EUSELACHII.

## Family *LAMNIDAE*.

## Genus CARCHARIOLAMNA nov.

*Diagnosis.*—The new genus *Carchariolamna* (Plate 13, figs. 1-4; text-fig. 1 *b*) is proposed for Selachian teeth from a boring at Balasore, having the dual characters of *Lamna* Cuvier (text-fig. 1 *c*) and *Carcharodon* Müller & Henle. It bears a close affinity with the Eocene genus *Carcharoides* Ameghino (text-fig. 1 *a*), from which it is distinguished by the less developed or totally absent lateral denticles, very finely serrated edges, and an almost erect and blunt crown.




TEXT-FIG. 1.—Fossil teeth of *Carcharoides* Ameghino, *Carchariolamna* gen. nov., and *Lamna* Cuvier.

*a. Carcharoides totuserratus* Ameghino (after Chapman); *b. Carchariolamna heroni* gen. *et* sp. nov.; *c. Lamna* sp. from the Salt Range (after Hora).

The teeth are solid throughout and are, therefore, referrable to the family Lamnidae and not to the Carcharinidae, in which the teeth are invariably hollow.

*Geno-type.*—*Carchariolamna heroni* gen. *et* sp. nov.

*Carchariolamna heroni* gen. *et* sp. nov.

(Plate 13, figs. 1-4; text-fig. 1 *b*.)

*Material.*—Specimens G. S. I. Type Nos. 16646—16651 (six isolated teeth or fragments of teeth). Collected by Mr. N. H. Cour-Palais at Balasore.

*Description of the Holotype.*—G. S. I. Type No. 16646, (Plate 13, fig. 1; text-fig. 1 *b*).—The tooth is of a moderate size and is very much like that of *Lamna* in its general facies. The base is broad and strong, and somewhat arched. The apical part is strong and erect, and tapers to the apex which is blunt. The external face of the crown is depressed and convex; it is provided with a weak median sulcus extending for a short distance from the junction of the base upwards. The internal face is also depressed, but is concave. The lateral cusps are small, blunt, and almost incipient. The edges of the crown are compressed, thin and very delicately serrated; the serrations do not extend to the base of the crown. The surface of the crown and the lateral denticles is smooth.

*Dimensions.*—Total length, 18 mm. (crown, 14·4 mm.; base, 3·6 mm.). Width of crown at base, not including cusps, 8·5 mm.; thickness, 3·9 mm.

*Description of co-types.*—The remaining specimens in the collection vary considerably from the type, but probably these variations are correlated with the different positions of the respective teeth in the jaws. In one specimen, G. S. I. Type No. 16647, (Plate 13, fig. 2), 11·7 mm. in total length, the base is considerably broader than the height of the crown. The lateral cusps are totally absent. The crown is delicately serrated in its upper half, while in the basal portion the edge is slightly crenulated. In another specimen, G. S. I. Type No. 16648, (Plate 13, fig. 3), 14·8 mm. in total length, the base is stout and narrow; the lateral denticles are absent and the edges of the crown are serrated only in the upper half. In a partially damaged tooth, G. S. I. Type No. 16649, (Plate 13, fig. 4), 12·9 mm. in total length, the lateral edges of the crown are serrated throughout and there are no lateral denticles. One broken tooth, G. S. I. Type No. 16650, was sectioned just above the base (Plate 13, fig. 4*a*) and it was found to be solid. In another tooth, G. S. I. Type No. 16651, in which the upper half of the crown is damaged, the lateral edges are serrated almost to the base; the

lateral denticles, though minute, are present and the base is akin to that of the holotype.

*Affinities.*—Relying on Zittel's (1932, p. 77) characterization of the various genera I referred the above material to *Carcharoides* Ameghino, but as this genus is so far known only from the Lower Tertiary formations of South America and Australia, and as the probability is that the Balasore rocks are younger, Dr. M. R. Sahni wished me to look into the identification of this material more closely. Unfortunately Ameghino's (1906) original description is not available in Calcutta, so photographs of the 4 teeth reproduced here were sent to the British Museum for determination. In reply Dr. E. I. White, in his letter dated the 12th July, 1938, wrote as follows :—

"From the photographs I do not believe that your specimens have anything to do with the genus *Carcharoides*, of which both the known species have triangular teeth and very well developed lateral denticles. To judge from the photographs I should say that your specimens are the teeth of a species of *Carcharinus*, in which, as you know, incipient lateral denticles are not infrequently developed."

Dr. White also directed my attention to Chapman's paper in which both the known species of *Carcharoides* are described and figured. After consulting Chapman's article (1917) and finding the serrations on the edges of the Balasore teeth quite different from those associated with the teeth of *Carcharinus* (=*Prionodon*), I sent the type-specimen to Dr. White with the permission of the Director, Geological Survey of India. After an examination of the tooth, Dr. White wrote as follows in his letter dated the 26th July, 1938 :—

"I must confess that I am rather puzzled by this particular tooth, as it really does not fit in properly with any of the forms with which I am familiar. I did not realise from your photographs that it was so worn, and that therefore the denticles might have been larger. It certainly does not seem to belong to any known species of Carcharinid, but, on the other hand, the form of the crown on the denticles is certainly different from that of the two species of *Carcharoides*, in which the crown is always triangular, as in true Lamnids, and the denticles are very large and the base correspondingly broad."

For placing the teeth correctly in either Lamnidae or Carcharinidae, Dr. White suggested to me to break a tooth in half and noted "Lamnid teeth are solid throughout, whereas Carcharinid teeth are usually hollow". In accordance with Dr. White's suggestion I sectioned one of the teeth (Plate 13, fig. 4 *a*) and found it to be solid. Other fragments of teeth in the collection were also found

to be solid. I sent the section and one broken tooth to Dr. White with my letter of the 2nd August, 1938, in which I made the following observations :—

> "In view of this (solid nature of teeth) and their general form they may be referred to the Lamnidae, but as they differ from *Lamna* and *Carcharoides* in the nature of their lateral edges I think it is desirable to refer them to a new genus. The other shark teeth from the same tube-well boring show Miocene affinities, and as *Carcharoides* is definitely an Eocene genus I think it would be advisable on this consideration also to keep them in a distinct genus. In several respects the new genus will be intermediate between *Carcharoides* and *Lamna*, in fact it will indicate the evolution of the *Lamna*-type and the *Oxyrhina*-type of teeth from the *Carcharoides*-type of teeth."

To this Dr. White in his letter, dated the 8th August, 1938, replied that "It does seem that the serrated teeth are solid ; indeed I took the liberty of cracking the one sectioned across the base to make certain that this part was also without a hollow".

In the above correspondence details are given of the probable affinities of the new genus, and the reasons why on morphological and stratigraphical grounds it has been found necessary to recognise it as a distinct genus. In the incipient development or total absence of the lateral denticles the new genus corresponds with *Oxyrhina* Ag. (Plate 13, figs. 5-6, text-fig. 2), but in the latter, as in *Lamna*, the lateral edges are smooth.

The presence of well-developed lateral denticles is a primitive feature in Selachian teeth (*vide* Smith, 1937) and therefore it would appear that among the Lamnidae *Carcharoides*, an extinct genus, represents the least specialized form. From *Carcharoides*, by the reduction in the size of the lateral denticles and the progressive reduction in the serrations on the edges, we can derive *Carchariolamna*, another extinct genus. By a further modification of the edges of the crown, which now became smooth, we get the two living genera *Lamna* and *Oxyrhina*, the former with lateral denticles and the latter without them. The discovery of the new genus has thus enabled to bridge over the gulf between *Carcharoides* on the one hand, and *Lamna* and *Oxyrhina* on the other.

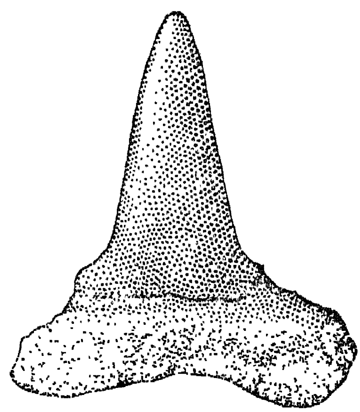
The new species of fossil sharks is associated with the name of Dr. A. M. Heron, Director, Geological Survey of India, in slight recognition of the manifold courtesies received by the author in his work on fossil material belonging to his department.

Genus OXYRHINA Agassiz.

(Plate 13, figs. 5-6; text-fig. 2.)

*Material.*—Specimens Nos. K 40/275*a* and K 40/275*b* (two isolated teeth). Collected by Mr. N. H. Cour-Palais at Balasore.

The two isolated teeth, which I have referred to *Oxyrhina*, are similar to those of *Lamna* but lack the lateral denticles. In one of the specimens, K 40/275*b*, (Plate 13, fig. 6), however, there are indications of minute lateral denticles. The base is broad and bilobed, and the cusp, which is smooth, is slightly curved inwards. The crown is placed vertically above the base and the apex is not very sharp. In general facies, these teeth, except for the smooth edges, correspond very closely with those of *Carchariolamna*.



TEXT-FIG. 2.—Fossil tooth of *Oxyrhina* Agassiz. ×4.

According to Zittel (1932, p. 77), *Oxyrhina* ranges from the Cretaceous to the recent times. Two species of the genus, *O. glaucus* M. & H. and *O. güntheri* (Murray), are known to occur in the seas of India at the present day.

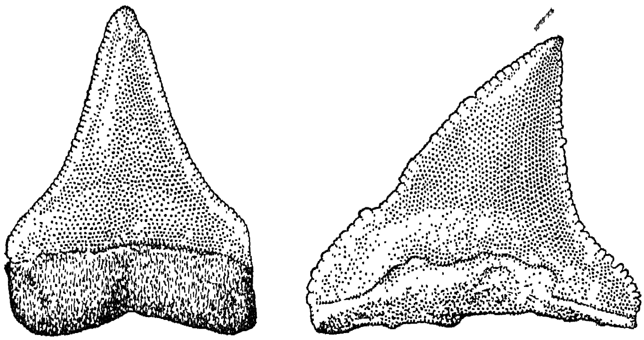
Family *CARCHARINIDAE.*

Genus PRIONODON Müller & Henle.

(Plate 13, figs. 7-10; text-fig. 3.)

*Material.*—Specimens Nos. K 40/275*c* to K 40/275*g* (eight isolated teeth and fragments), collected by Mr. N. H. Cour-Palais at Balasore), and K 40/311 (four isolated teeth), collected by Mr. J. G. Gilson at Scro.

The fishes of the genus *Prionodon* are the dominant sharks of the present day and are represented by a large number of living species. Numerous fossil species have been described from the Eocene and later formations.



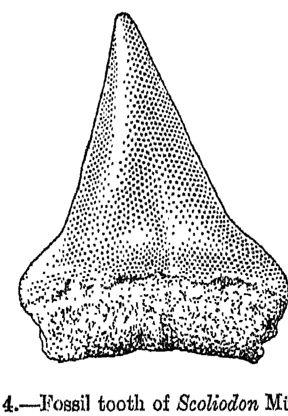
TEXT-FIG. 3.—Two fossil teeth of *Prionodon* Müller & Henle. ×3.

The teeth of *Prionodon* are compressed, subtriangular and provided with a single cusp, the edges of which are serrated to the apex. The teeth vary in form and size according to their respective positions in the jaws.

Besides the material enumerated above, there are several unsatisfactory fragments of *Prionodon* teeth among the indetermined lot.

Genus SCOLIODON Müller & Henle.

(Plate 13, figs. 11-14; text-fig. 4.)



TEXT-FIG. 4.—Fossil tooth of *Scoliodon* Müller & Henle. ×4.

*Material.*—Specimens Nos. K 40/275*h*—275*k* (four isolated teeth). Collected by Mr. N. H. Cour-Palais at Balasore.

The four teeth referred to the genus *Scoliodon* possess smooth edges. The base is broad but not swollen. The cusp is almost erect, triangular and sharply pointed.

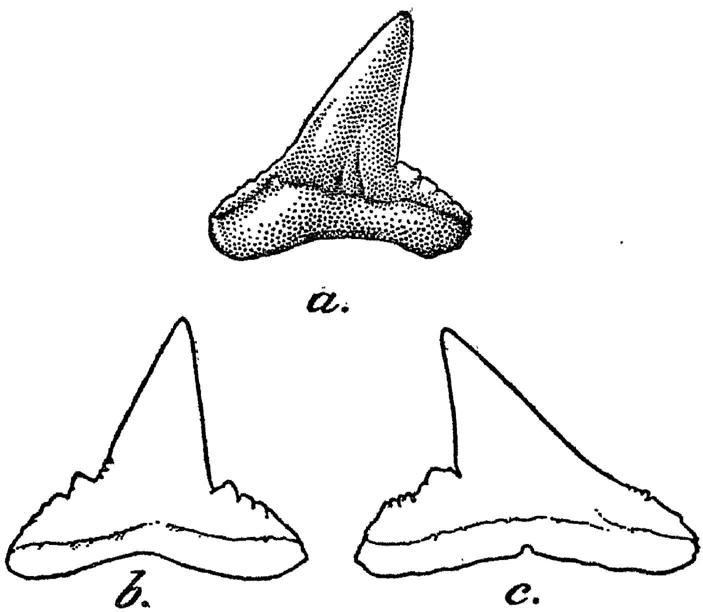
*Scoliodon* is a widely distributed genus of the present-day sharks and is represented by about a dozen species. Its fossil remains date as far back as the Lower Eocene.

### Genus HYPOPRION Müller & Henle.

(Plate 13, fig. 15; text-figs. 5*a*, *b*, *c*.)

*Material.*—Specimen No. K 40/275*l* (one isolated tooth). Collected by Mr. N. H. Cour-Palais at Balasore.

There is one, relatively small, isolated tooth in which the cusp




TEXT-FIG. 5.—Teeth of *Hypoprion* Müller & Henle.

*a*. Fossil tooth from Balasore. ×4; *b*. Sixth upper tooth of *H. macloti* Müll. & Henle. ×12; *c*. Third upper tooth of same. ×10.
Length of specimen including caudal 492 mm.

is oblique with smooth edges except at the base where it is coarsely serrated on one side and crenulated on the other. Similar teeth are usually characteristic of the upper dentition of *Hypoprion* M. & H.

Two living species of the genus are found in the seas of India—*H. macloti* M. & H. and *H. hemidon* M. & H. I have examined the teeth of the former and found considerable variation in regard to the number of denticulations on the two sides of the base (text-fig. 5 *b* and *c*).

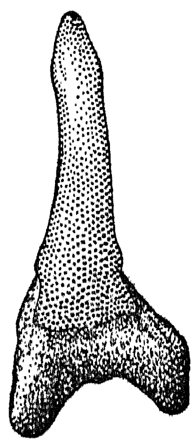
The genus *Hypoprion* dates back to the Miocene. So far as I am aware no earlier record of the genus is known.

### Genus APRIONODON Gill.

(Plate 13, figs. 16-20 ; text-fig. 6.)

*Material.*—Specimens Nos. K 40/275*m*—275*q* (five isolated teeth). Collected by Mr. N. H. Cour-Palais at Balasore.

The five isolated teeth referred to the genus *Aprionodon* vary from one another in shape and size, presumably owing to their different positions in the jaws. They are compressed with narrow inwardly curved cusps which are smooth along the edges. Their bases, where preserved, are fairly broad and bilobed. The cusps are lanceolate towards their terminations and are devoid of any ornamentation.



TEXT-FIG. 6.—Fossil tooth of *Aprionodon* Gill. ×4.

Among the three living species assigned by Garman (1913, pp. 117-119) to *Aprionodon* the teeth are stated to be lanceolate in *A. acutidens* (Rüpp.). The range of distribution of *A. acutidens* is given as "Indian Ocean and Archipelago ; Red Sea". Unfortunately

there is no specimen of the species in the collection of the Indian Museum, but it seems probable that the fossil teeth from Balasore are either referrable to this species or to some other allied form.

*Aprionodon* is known from the Tertiary formations to the recent times.

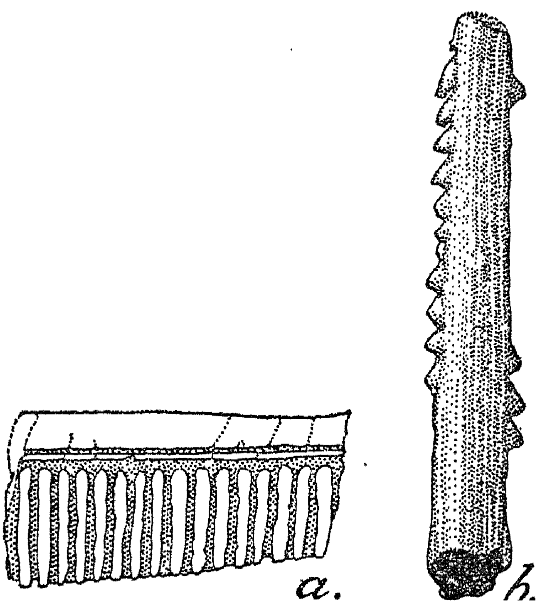
### Order BATOIDEI.

### Family *MYLIOBATIDAE.*

### Genus MYLIOBATUS Cuvier.

(Plate 13, figs. 21-24 (teeth); figs. 25 (spine); text-figs. 7*a*, *b*.)

*Material*: Teeth.—Specimen Nos. K 40/275*r* (one fragment); K 40/277*a*—277*d* (four fragments), K 40/280 (one fragment), collected by Mr. N. H. Cour-Palais at Balasore; and K 40/314 (five fragments), collected by Mr. J. G. Gilson at Soro.




TEXT-FIG. 7.—*Myliobatid* fish-remains.
*a*. Fragment of isolated centre-tooth of *Myliobatus* Cuvier. ×3; *b*. Fragment of tail-spine. ×1½.

Spines.—Specimen Nos. K 40/281 (a portion of a spine), collected by Mr. N. H. Cour-Palais at Balasore; and K 40/315 (a small

fragment with 3 teeth on one side only), collected by Mr. J. G. Gilson at Soro.

The Myliobatid remains are very unsatisfactory for a specific determination, but there seems hardly any doubt that they belong to the genus *Myliobatus* Cuvier. All the specimens of teeth are fragments of isolated centre-teeth. Though the tail-spines of the Myliobatid rays are of frequent occurrence in the Tertiary rocks they have not been found to exhibit any definite features of diagnostic value. The two fragments of tail-spines represented in the collections, owing to their association with undoubted Myliobatid teeth, possibly are referrable to the genus *Myliobatus*.

Though as a family the Myliobatidae date back to the Cretaceous period, most of the surviving genera, such as *Myliobatus* Cuvier, *Rhinoptera* Müller, *Aetiobatus* M. & H., etc., are well represented in the Tertiary formations by isolated teeth and spines.

## Class PISCES.

## Sub-Class TELEOSTEI.

## Super-Order OSTARIOPHYSI.

## Order SILUROIDEA.

## Family *ARIIDAE*.

### Genus ARIUS Cuvier.

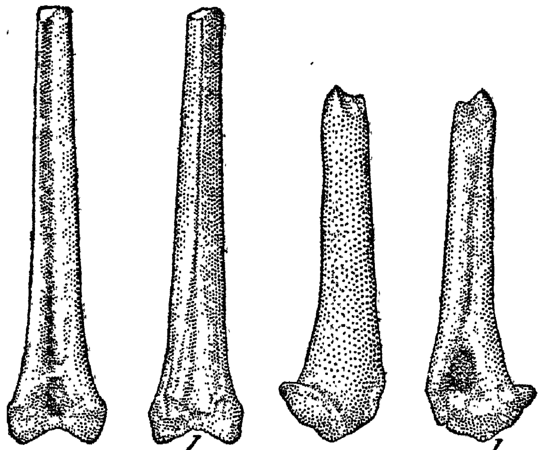
(Plate 13, figs. 26-29; text-figs. 8*a*, *b*, *c*, *d*.)

*Material.*—Specimens Nos. K 40/279 *a*, *b* (two fragments of basal portions of spines; dorsal spine and left pectoral spine). Collected by Mr. N. H. Cour-Palais at Balasore.

In both the fragments the preserved basal portions of the shafts are without any serrations, but this is not unusual even among some of the living members of the genus *Arius*, in some of which the serrations are present only near the terminal parts of the spines. From the nature of the articular surfaces of the two fragments it is possible to determine them as dorsal and pectoral spines respectively.

The dorsal spine, K 40/279 *a*, (pl. 13, figs. 26-27; text-fig. 8, *a* and *b*) is grooved along the posterior border; it is flattened

anteriorly and grooved at the proximal end. The spine is compressed from side to side and ornamented with faintly marked longitudinal ridges.



TEXT-FIG. 8.—Fragments of dorsal and pectoral spines of a Siluroid fish. ×2.
*a.* Posterior view of dorsal spine fragment; *b.* Anterior view of same; *c.* Dorsal view of pectoral spine fragment; *d.* Ventral view of same.

A large portion of the articular head of the pectoral spine, K 40/279 *b*, (Pl. 13, figs. 28-29; text-fig. 8, *c* and *d*) is broken off. The shaft is greatly compressed and along the ventral surface of its proximal portion there is a fairly deep fossa and a groove in its continuation. The spine is devoid of any ornamentation.

The identification of these two fragments is only provisional, as the fragments are rather of a generalised nature.

The Siluroids are among the dominant fishes of the present day and date back to the Eocene period.

Super-Order PERCOMORPHI.

Order SCOMBROIDEA.

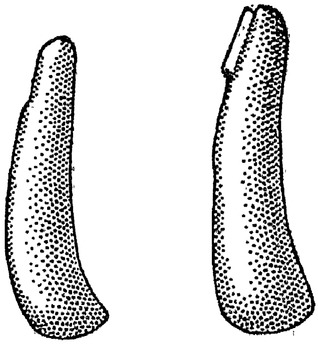
Family *TRICHIURIDAE.*

Genus TRICHIURUS Linnaeus.

(Plate 13, figs. 30-31; text-fig. 9.)

*Material.*—Specimens Nos. K 40/313 *a*, *b* (two isolated teeth). Collected by Mr. J. G. Gilson at Soro.

The teeth are compressed, smooth and fairly large; they are slightly curved. I have compared these teeth with those of *Trichiurus savala* Cuv. & Val. and found a close agreement between them.



TEXT-FIG. 9.—Fossil teeth of *Trichiurus* Linnaeus. ×4.

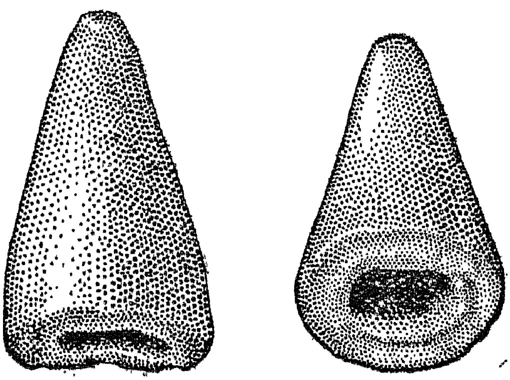
Dr. E. I. White also examined the two specimens and found that they very likely belong to *Trichiurus* "but their state is such that I am quite certain that they are not specifically identifiable".

The Trichiuridae range from the Eocene to the present times.

*Incertae Sedis.*

(Plate 13, figs. 32-33; text-fig. 10.)

*Material.*—Nos. K 40/276 *a, b* (two isolated teeth). Collected by Mr. N. H. Cour-Palais at Balasore.



*a* *b*

TEXT-FIG. 10.—Apical portion of a fossil Scombrioid tooth. ×5.
*a*. Side view; *b*. Slightly tilted view to show hollow nature of tooth.

The two isolated teeth, to which I have not been able to assign any definite generic position, probably represent the apical portions

of some type of Scombrioid teeth. The teeth are compressed and of different form and sizes. One large tooth (Pl. 13, fig. 32; text-fig. 10), probably a principal tooth of the dentary or palatine, is fairly broad, symmetrical and bent inwards; it gradually tapers to the apex. The other tooth, probably the lamiary tooth of pre-maxilla or dentary, is narrower, somewhat asymmetrical and only slightly bent. Both the teeth are ornamented with fine longitudinal ridges and are hollow; the central cavity being fairly wide.

Superficially the fossil teeth appear similar to those of *Sphyraena* Artedi, but the teeth of the present-day species of the genus that I have examined are solid.

Owing to a superficial resemblance of these teeth to those of *Pristis ensidens* Leidy (1877) and *P. cudmorei* Chapman (1917), I got confused regarding their systematic position, so I sent the material to Dr. E. I. White. He found the two teeth described above as belonging to an indeterminable genus of Scombrioid fishes; while another tooth-like structure, K 40/276 *c*, (Plate 13, fig. 34) he considers as the finger from the claw of a crab.

The modern Scombrioid fishes, as a whole, do not date back to an earlier period than the Eocene.

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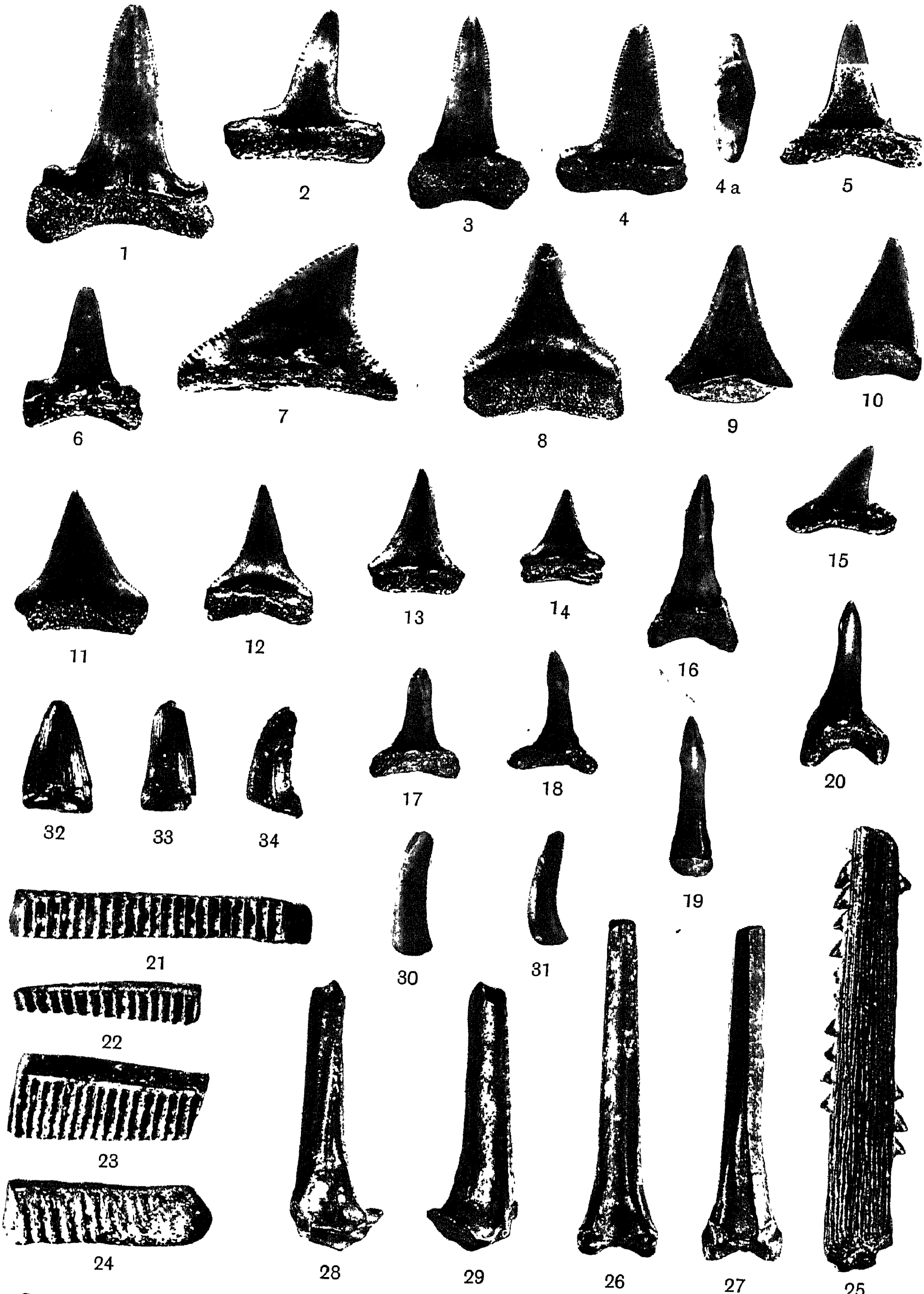
## EXPLANATION OF PLATE.

### *Fossil Fish-Remains from Balasore.*

FIGS. 1-4.—Teeth of *Carchariolamna heroni* gen. *et* sp. nov. ×2.
FIGS. 5-6.—Teeth of *Oxyrhina* Agassiz. ×2.
FIGS. 7-10.—Teeth of *Prionodon* Müller & Henle. ×2.
FIGS. 11-14.—Teeth of *Scoliodon* Müller & Henle. ×2.
FIG. 15.—Tooth of *Hypoprion* Müller & Henle. ×2.
FIGS. 16-20.—Teeth of *Aprionodon* Gill. ×2.
FIGS. 21-24.—Fragments of isolated centre-teeth of *Myliobatus* Cuvier. ×2.
FIG. 25.—A portion of the tail-spine of a Myliobatid fish. ×1½.
FIG. 26.—Posterior view of a dorsal spine fragment of a Siluroid fish, probably *Arius* Cuvier. ×2.
FIG. 27.—Anterior view of above. ×2.
FIG. 28.—Ventral view of a pectoral spine fragment of a Siluroid fish, probably *Arius* Cuvier. ×2.
FIG. 29.—Dorsal view of above. ×2.
FIGS. 30-31.—Teeth of *Trichiurus* Linn. ×2.
FIGS. 32-33.—Apical portions of Scombrioid teeth. ×2.
FIG. 34.—Finger from the claw of a crab. ×2.




S. C. Mandul, Photo.

G. S. I., Calcutta.

FOSSIL FISH REMAINS FROM BALASORE.

RECORDS

of the

INDIAN MUSEUM

Vol. XLII, Part II, pp. 365—374

# On a collection of Fish from the headwaters of the Mahanadi River, Raipur District, C. P.

By

SUNDER LAL HORA

CALCUTTA:

JUNE, 1940.

# ON A COLLECTION OF FISH FROM THE HEADWATERS OF THE MAHANADI RIVER, RAIPUR DISTRICT, C. P.

*By* SUNDER LAL HORA, *D.Sc., F.R.S.E., F.N.I., Assistant Superintendent, Zoological Survey of India, Calcutta.*

In December 1939 my colleague, Dr. H. S. Rao, made a survey of the aquatic fauna of the Mahanadi river and its affluents in the Raipur District of the Central Provinces. The Mahanadi rises near Sihawa in Dhamtari Tahsil and the area surveyed by Dr. Rao comprises a part of the headwaters of the river. It may be noted that the Sihawa range, the general altitude of which ranges between 2,000 to 2,500 feet, forms a watershed between the affluents of the Mahanadi and those of the Godavari. The general characteristic of the Mahanadi and its affluents is that the beds of these streams are wide wastes of sand, dry for more than half the year, and never containing much water except during seasons of high floods. At the time of Dr. Rao's visit, therefore, most of the streams had either scanty flowing water or were cut up into pools and puddles, which were sometimes connected by a small trickle of water. Only in a very few instances fish were collected from rocky streams. It is no wonder, therefore, that the collection under report comprises young specimens of a large number of pool-dwelling species. Incidentally, the material collected shows that most of the small freshwater fishes in this part of India breed in the autumn months after the cessation of the monsoon. I give below brief descriptions, based on Dr. Rao's notes, of the localities from which fish were collected, and the lists of fishes obtained from each locality. A general account of the collection and the zoogeographical significance of some of the species represented are also given.

## DESCRIPTIONS OF LOCALITIES WITH LISTS OF FISHES COLLECTED FROM EACH.

*Bokori Nallah, about 3 miles North-East of Kusumkhunta.* 7.xii.1939.

It is a small stream broken up into pools of depths varying from 2 to 5 feet, with sandy bottom which, in parts, is strewn with large stones over which there is a slight trickle of water. Weeds of various types, and algae occur in abundance.

| | mm. | Specimens. |
|---|---|---|
| *Brachydanio rerio* (Ham.) .. .. .. | 15—24 | 9 |
| *Rasbora daniconius* (Ham.) .. .. .. | 41—43 | 3 |
| *Barbus* (*Puntius*) *ticto* Ham. .. .. | 28 | 1 |
| *Lepidocephalichthys guntea* (Ham.) .. .. | 43 | 1 |

*Village tank, Singpur.* 9.xii.1939.

The tank is used for washing and bathing; it is overgrown with lilies, *Elodea*, and other water plants. Near the edge of the tank a species of Scrophularinae with spines and blue flowers and the reeds of a species of Cyperaceae are common.

| | mm. | Specimens. |
|---|---|---|
| *Brachydanio rerio* (Ham.) .. .. .. | 24—29 | 4 |
| *Rasbora daniconius* (Ham.) .. .. .. | 32—71 | 3 |
| *Barbus* (*Puntius*) *sophore* Ham. .. .. | 67 | 1 |

*'Jheel' at Nagri on the Raipur Forest Tramway.* 11.xii.1939.

The 'jheel' is about ½ a mile from the Forest Rest House at Nagri; it is situated in an open maidan and is surrounded by rice fields on all sides. It is apparently fed by rains as no streams of any size are to be seen in the vicinity. The 'jheel' is full of weeds of all kinds—*Potamogeton, Elodea, Trapa spinosa,* lilies, etc. Various grasses grow at the edge, and a few strands of filamentous algae are also seen.

| | mm. | Specimens. |
|---|---|---|
| *Brachydanio rerio* (Ham.) | 19—29 | 26 |
| *Esomus danricus* (Ham.) | 36—42 | 2 |
| *Barbus* (*Puntius*) *ticto* Ham. | 30—40 | 2 |
| *Lepidocephalichthys guntea* (Ham.) | 24—56 | 19 |
| *Ophicephalus gachua* Ham. | 70 | 1 |
| *Ophicephalus punctatus* Bloch | 65 | 1 |
| *Nandus nandus* (Ham.) | 83 | 1 |

*Mahanadi river at Sihawa.* 12.xii.1939.

| | mm. | Specimens |
|---|---|---|
| *Barilius* prox. *bendelisis* Ham. | 11—19 | 49 |
| *Brachydanio rerio* (Ham.) | 15—29 | 33 |
| *Barbus* (*Puntius*) *ticto* Ham. | 22—37 | 2 |
| *Nemachilus denisonii* Day | 25 | 1 |

*Tank in Forest Village about 4 miles from Sihawa.* 13.xii.1939.

The tank was full of weeds of all kinds, lilies, *Cyperus*, etc.

| | mm. | Specimens. |
|---|---|---|
| *Rasbora daniconius* (Ham.) | 30—41 | 5 |
| *Amblypharyngodon mola* (Ham.) | 20 | 1 |
| *Lepidocephalichthys guntea* (Ham.) | 25—44 | 8 |
| *Ophicephalus gachua* Ham. | 106 | 1 |

*Biweekly Market at Sihawa.* 13.xii.1939.

| | mm. | Specimens |
|---|---|---|
| *Rhynchobdella aculeata* (Bloch) | 109—122 | 2 |
| *Barilius bendelisis* Ham. | 46—150 | 9 |
| *Brachydanio rerio* (Ham.) | 21—23 | 2 |
| *Rasbora daniconius* (Ham.) | 42—71 | 8 |
| *Barbus* (*Puntius*) *dorsalis* (Jerdon) | 44—74 | 20 |
| *Barbus* (*Puntius*) *guganio* (Ham.) | 29—33 | 10 |
| *Barbus* (*Puntius*) *sarana* (Ham.) | 81—161 | 5 |
| *Barbus* (*Puntius*) *ticto* Ham. | 32—42 | 26 |
| *Garra mullya* (Sykes) | 69—97 | 2 |
| *Labeo boggut* (Sykes) | 109—116 | 2 |
| *Lepidocephalichthys guntea* (Ham.) | 32—60 | 14 |
| *Mystus cavasius* (Ham.) | 49—89 | 4 |
| *Mystus tengara* (Ham.) | 48—70 | 3 |
| *Mystus vittatus* (Bloch) | 44—72 | 16 |
| *Bagarius bagarius* (Ham.) | 287 | 1 |
| *Ophicephalus gachua* Ham. | 92 | 1 |
| *Nandus nandus* (Ham.) | 98 | 1 |

*Mahanadi river before its junction with the Balka Nallah about 3 miles from Sihawa.* 14.xii.1939.

The Mahanadi proper before it receives the Balka Nallah is a deep-cut stream with high banks. In places it is 7-10 feet deep. The bottom is muddy ; in places it is sandy and strewn over with small pebbles.

| | mm. | Specimens. |
|---|---|---|
| *Laubuca laubuca* (Ham.) | 22—36 | 11 |
| *Barilius bendelisis* Ham. | 35 | 2 |
| *Brachydanio rerio* (Ham.) | 13—30 | 48 |
| *Esomus danricus* (Ham.) | 40—41 | 2 |
| *Rasbora daniconius* (Ham.) | 30 | 1 |
| *Barbus* (*Puntius*) *gelius* Ham. | 18 | 1 |
| *Barbus* (*Puntius*) *guganio* (Ham.) | 26—31 | 2 |
| *Barbus* (*Puntius*) *ticto* Ham. | 20—41 | 55 |
| *Nemachilus botia* (Ham.) | 22—28 | 2 |
| *Nemachilus denisonii* Day | 21—42 | 21 |
| *Lepidocephalichthys guntea* (Ham.) | 29—65 | 52 |
| *Mystus tengara* (Ham.) | 42—48 | 3 |
| *Erethistes hara* (Ham.) | 37 | 1 |
| *Ophicephalus punctatus* Bloch | 102 | 1 |

*Balka Nallah about 3 miles from Sihawa.* 14.xii.1939.

The Balka is a sandy stream with only ankle-deep water in which algae and other weeds occur.

| | mm. | Specimens. |
|---|---|---|
| *Laubuca laubuca* (Ham.) | 25—29 | 13 |
| *Barilius* prox. *bendelisis* Ham. | 16—23 | 3 |
| *Brachydanio rerio* (Ham.) | 16—31 | 46 |
| *Barbus* (*Puntius*) *gelius* Ham. | 17 | 1 |
| *Barbus* (*Puntius*) *ticto* Ham. | 25—34 | 15 |
| *Lepidocephalichthys guntea* (Ham.) | 43—48 | 7 |

*Muddy road-side pools between Sihawa and Birgudi.* 15.xii.1939.

| | mm. | Specimens. |
|---|---|---|
| *Brachydanio rerio* (Ham.) | 10—18 | 36 |
| *Barbus* (*Puntius*) *ticto* Ham. | 12—32 | 12 |

*Village tank near Birgudi about 3 miles from Sihawa.* 15.xii.1939.

The tank is used as a buffalo-wallow ; it is overgrown with reeds (Cyperaceae) and weeds (*Potamogeton* and *Elodea*) of various kinds, and its sides are swampy.

| | mm. | Specimens. |
|---|---|---|
| *Brachydanio rerio* (Ham.) | 15—25 | |
| *Barbus* (*Puntius*) *sophore* Ham. | 15—34 | |

*Small, deep stream close to the Forest Rest House at Gattasilli.* 16.xii.1939.

| | mm. | Specimens |
|---|---|---|
| *Brachydanio rerio* (Ham.) | 9—15 | |

*Ama Nallah about 2 miles from Gattasilli.* 17.xii.1939.

A shallow stream on the edge of the forest at Gattasilli in the Birgudi range. The bottom is flat and sandy with a few rocks here and there.

The water is only ankle-deep, and there is a layer of green algae at the bottom. Many patches of long trailing grass also occur.

| | mm. | Specimens. |
|---|---|---|
| *Brachydanio rerio* (Ham.) .. .. .. | 12—35 | 206 |
| *Esomus danricus* (Ham.) .. .. .. | 25—46 | 39 |
| *Rasbora daniconius* (Ham.) .. .. .. | 40—68 | 4 |
| *Barbus (Puntius) sophore* Ham. .. .. | 42 | 1 |
| *Barbus (Puntius) ticto* Ham. .. .. | 17—51 | 16 |
| *Lepidocephalichthys guntea* (Ham.) .. .. | 36—53 | 9 |

*Nenginallah swamp near Gattasilli.* 18.xii.1939.

The sides of the swamp are overgrown with reeds, while the water is full of *Potamogeton*, *Cyperus*, filamentous algae, and other weeds.

| | mm. | Specimens. |
|---|---|---|
| *Brachydanio rerio* (Ham.) .. .. . | 20—27 | 29 |
| *Barbus (Puntius) guganio* (Ham.) .. . | 21—25 | 2 |
| *Barbus (Puntius) sophore* Ham. .. . | 14—19 | 4 |
| *Barbus (Puntius) ticto* Ham. .. . | 20—26 | 2 |
| *Lepidocephalichthys guntea* (Ham.) .. . | 50—70 | 2 |
| *Ophicephalus punctatus* Bloch .. . | 46—61 | 4 |
| *Nandus nandus* (Ham.) .. .. . | 46—51 | 2 |

*Small stream and swamp near Dokal Forest Rest House.* 20.xii.1939.

Some portions of the stream are muddy while others are sandy; it flows over rocky ground before reaching the swampy portion. The edges of the stream are overgrown with grass, weeds and shrubs. In the rocky portion there are small rounded buttons of mucilaginous light green algae in small patches.

The swamp was obviously lately cultivated as the stumps of paddy 2 to 3 feet high, which are still to be seen over it, show. Puddles of water full of *Potamogeton* are left in various parts of the swamp.

| | mm. | Specimens. |
|---|---|---|
| *Brachydanio rerio* (Ham.) .. .. .. | 18—34 | 157 |
| *Danio aequipinnatus* (McClell.) .. .. | 53—60 | 5 |
| *Esomus danricus* (Ham.) .. .. .. | 33—47 | 36 |
| *Rasbora daniconius* (Ham.) .. .. .. | 34—92 | 29 |
| *Barbus (Puntius) dorsalis* (Jerdon) .. .. | 36—41 | 2 |
| *Lepidocephalichthys guntea* (Ham.) .. .. | 48 | 1 |
| *Nemachilus denisonii* Day .. .. .. | 21—43 | 23 |
| *Ophicephalus gachua* Ham. .. .. .. | 64—73 | 4 |

*Morrumsilli Reservoir, about 5 miles to the south-west of Banroud.* 23.xii.1939.

The reservoir is formed by putting a dam across the Silari river and is about 180 sq. miles in extent. Below the dam the Silari continues as a small stream. There are great numbers of fish of all kinds, but it is difficult to catch them without suitable appliances.

| | mm. | Specimens. |
|---|---|---|
| *Brachydanio rerio* (Ham.) .. .. .. | 22—29 | 11 |
| *Rasbora daniconius* (Ham.) .. .. .. | 36 | 1 |
| *Barbus (Puntius) ticto* Ham. .. .. | 16 | 1 |
| *Lepidocephalichthys guntea* (Ham.) .. .. | 30 | 1 |
| *Xenentodon cancila* (Ham.) .. .. .. | 41 | 1 |

*Mahanadi river at Rudri.* 24.xii.1939.

The Mahanadi river is situated at a distance of about one mile from the P. W. D. Inspection Bungalow at Rudri ; it is about a mile broad. The main stream flows about the centre of the bed and is knee-to waist-deep in many places. The bed is mostly sandy though, in places, sand is mixed with mud. The current is fairly swift.

| | mm. | Specimens. |
|---|---|---|
| *Mastacembelus pancalus* (Ham.) | 57—73 | 2 |
| *Rasbora daniconius* (Ham.) | 19 | 1 |
| *Barilius* prox. *bendelisis* Ham. | 10—17 | 4 |
| *Barbus* (*Puntius*) *dorsalis* (Jerdon) | 30—48 | 27 |
| *Barbus* (*Puntius*) *guganio* (Ham.) | 19—23 | 7 |
| *Barbus* (*Puntius*) *sophore* Ham. | 24 | 1 |
| *Barbus* (*Puntius*) *ticto* Ham. | 15—34 | 133 |
| *Oreichthys cosuatus* (Ham.) | 21—25 | 3 |
| *Lepidocephalichthys guntea* (Ham.) | 36—54 | 86 |
| *Nemachilus botia* (Ham.) | 26—40 | 5 |
| *Ophicephalus gachua* Ham. | 70 | 1 |

*Dhamtari Bazaar* (*Mahanadi river*). 24.xii.1939.

| | mm. | Specimens. |
|---|---|---|
| *Mastacembelus pancalus* (Ham.) | 44—106 | 5 |
| *Rhynchobdella aculeata* (Bloch) | 120 | 1 |
| *Chela bacaila* Ham. | 54—75 | 3 |
| *Barilius barna* Ham. | 58—66 | 2 |
| *Barilius bendelisis* Ham. | 46—140 | 15 |
| *Rasbora daniconius* (Ham.) | 28—53 | 24 |
| *Amblypharyngodon mola* (Ham.) | 44—64 | 3 |
| *Aspidoparia morar* (Ham.) | 32—82 | 17 |
| *Barbus* (*Puntius*) *dorsalis* (Jerdon) | 42—61 | 43 |
| *Barbus* (*Puntius*) *gelius* Ham. | 27 | 1 |
| *Barbus* (*Puntius*) *sarana* (Ham.) | 130—143 | 3 |
| *Barbus* (*Puntius*) *sophore* Ham. | 40—59 | 36 |
| *Barbus* (*Puntius*) *tetrarupagus* (McClell.) | 49—89 | 5 |
| *Barbus* (*Puntius*) *ticto* Ham. | 30—55 | 4 |
| *Labeo boggut* (Sykes) | 35—84 | 2 |
| *Lepidocephalichthys guntea* (Ham.) | 28—54 | 10 |
| *Nemachilus botia* (Ham.) | 45—56 | 4 |
| *Clarias batrachus* (Linn.) | 140—153 | 2 |
| *Heteropneustes fossilis* (Bloch) | 92—96 | 2 |
| *Mystus aor* (Ham.) | 190—195 | 2 |
| *Mystus cavasius* (Ham.) | 65—86 | 5 |
| *Mystus tengara* (Ham.) | 46—78 | 15 |
| *Mystus vittatus* (Bloch) | 58—65 | 6 |
| *Pseudeutropius atherinoides* (Bloch) | 50 | 2 |
| *Xenentodon cancila* (Ham.) | 230 | 1 |
| *Ophicephalus punctatus* Bloch | 86—118 | 2 |
| *Ambassis ranga* (Ham.) | 30—32 | 2 |
| *Nandus nandus* (Ham.) | 48—125 | 6 |
| *Badis badis* (Ham.) | 17 | 1 |

*Mahanadi Irrigation Canal, Rudri.* 25.xii.1939.

The water is standing in disconnected pools at various places throughout the canal. The sides of the canal are rocky and the bed is strewn

over with small and large pieces of stone. The bed is pebbly, except in fairly deep water where it is muddy.

| | mm. | Specimens. |
|---|---|---|
| *Mastacembelus armatus* (Lacép.) .. .. | 94 | 1. |
| *Chela bacaila* Ham. .. .. .. | 95—107 | 2 |
| *Laubuca laubuca* (Ham.) .. .. .. | 29 | 1 |
| *Brachydanio rerio* (Ham.) .. .. .. | 22—24 | 2 |
| *Rasbora daniconius* (Ham.) .. .. .. | 36—44 | 4 |
| *Barbus (Puntius) guganio* (Ham.) .. .. | 34 | 1 |
| *Barbus (Puntius) sophore* Ham. .. .. | 83 | 1 |
| *Barbus (Puntius) tetrarupagus* (McClell.) .. .. | 93 | 1 |
| *Barbus (Puntius) ticto* Ham. .. .. | 33—57 | 64 |
| *Garra mullya* (Sykes) .. .. .. | 73—85 | 2 |
| *Oreichthys cosuatus* (Ham.) .. .. .. | 33—34 | 2 |
| *Lepidocephalichthys guntea* (Ham.) .. .. | 33—48 | 5 |
| *Nemachilus botia* (Ham.) .. .. .. | 35—58 | 19 |
| *Nemachilus denisonii* Day .. .. .. | 22—50 | 20 |
| *Mystus cavasius* (Ham.) .. .. .. | 93—98 | 2 |
| *Amblyceps mangois* (Ham.) .. .. .. | 26—49 | 7 |
| *Ambassis ranga* (Ham.) .. .. .. | 52 | 1 |
| *Glossogobius giuris* (Ham.) .. .. .. | 93 | 1 |

## SYSTEMATIC ACCOUNT.

The collection under report comprises 1,872 specimens of 43 species. The systematic position of these species is shown in the following table :

Family MASTACEMBELIDAE.

1. *Mastacembelus armatus* (Lacépède).
2. *Mastacembelus pancalus* (Hamilton).
3. *Rhynchobdella aculeata* (Bloch).

Family CYPRINIDAE.

Subfamily *ABRAMADINAE.*

4. *Chela bacaila* Hamilton.
5. *Laubuca laubuca* (Hamilton).

Subfamily *RASBORINAE.*

6. *Barilius barna* Hamilton.
7. *Barilius bendelisis* Hamilton.
8. *Brachydanio rerio* (Hamilton).
9. *Danio aequipinnatus* (McClelland).
10. *Esomus danricus* (Hamilton).
11. *Rasbora daniconius* (Hamilton).

Subfamily *CYPRININAE.*

12. *Amblypharyngodon mola* (Hamilton).
13. *Aspidoparia morar* (Hamilton).
14. *Barbus (Puntius) dorsalis* (Jerdon).
15. *Barbus (Puntius) gelius* Hamilton.
16. *Barbus (Puntius) guganio* (Hamilton).
17. *Barbus (Puntius) sarana* (Hamilton).
18. *Barbus (Puntius) sophore* Hamilton.
19. *Barbus (Puntius) tetrarupagus* (McClelland).
20. *Barus (Puntius) ticto* Hamilton.
21. *Garra mullya* (Sykes).
22. *Labeo boggut* (Sykes).
23. *Oreichthys cosuatus* (Hamilton).

Family COBITIDAE.

24. *Lepidocephalichthys guntea* (Hamilton).
25. *Nemachilus botia* (Hamilton).
26. *Nemachilus denisonii* Day.

Family BAGRIDAE.

27. *Mystus aor* (Hamilton).
28. *Mystus cavasius* (Hamilton).
29. *Mystus tengara* (Hamilton).
30. *Mystus vittatus* (Bloch).

Family AMBLYCEPIDAE.

31. *Amblyceps mangois* (Hamilton).

Family SISORIDAE.

32. *Erethistes hara* (Hamilton).
33. *Bagarius bagarius* (Hamilton).

Family SCHILBEIDAE.

34. *Pseudeutropius atherinoides* (Bloch).

Family CLARIIDAE.

35. *Clarias batrachus* (Linnaeus).

Family HETEROPNEUSTIDAE.

36. *Heteropneustes fossilis* (Bloch).

Family BELONIDAE.

37. *Xenentodon cancila* (Hamilton).

Family OPHICEPHALIDAE.

38. *Ophicephalus gachua* Hamilton.
39. *Ophicephalus punctatus* Bloch.

Family AMBASSIDAE.

40. *Ambassis ranga* (Hamilton).

Family NANDIDAE.

41. *Nandus nandus* (Hamilton).

Family PRISTOLEPIDAE.

42. *Badis badis* (Hamilton).

Family GOBIIDAE.

43. *Glossogobius giuris* (Hamilton).

Of the 43 species listed above, 23 belong to the order Cyprinoidea (20 Cyprinidae and 3 Cobitidae), 10 to the order Siluroidea (4 Bagridae, 1 Amblycepidae, 2 Sisoridae, 1 Schilbeidae, 1 Clariidae and 1 Heteropneustidae), while the remaining ten species are of the families Mastacembelidae (3), Belonidae (1), Ophicephalidae (2), Ambassidae (1), Nandidae (1), Pristolepidae (1) and Gobiidae (1). With the exception of a few small species of carp-minnows all the others are fairly well known and do not call for any special comments from a systematic point of view. However, notes are given on the distribution of *Rhynchobdella aculeata*, *Nemachilus denisonii* and *Amblyceps mangois*.

From a zoogeographical point of view the occurrence of *Amblyceps mangois* in the Mahanadi system, and of *Barbus* (*Puntius*) *dorsalis* and *Nemachilus denisonii* so far north and east are very significant as showing former hydrographic relations of the present-day river systems. It may be noted that the Sihawa range is only a spur of the once extensive Satpura Mountains.

### **Rhynchobdella aculeata** (Bloch).

1938. *Rhynchobdella aculeata*, Shaw and Shebbeare, *Journ. Roy. As. Soc. Bengal, Science* III, p. 126, text-fig. 128, 1937.

Regarding the habitat of *Rhynchobdella aculeata*, Day[1] made the following observations :

> " Brackish waters within tidal influence, also throughout the deltas of large Indian, Burmese, and Sind rivers, but appears to be absent from the northern portion of the Punjab and the Malabar coast : it extends to Borneo and the Moluccas : attaining about 15 inches in length. It conceals itself in the mud, and becomes drowned if placed in water so as to be unable to reach the surface, apparently requiring to respire air directly."

In 1935, while recording observations on the mode of aerial respiration in Mastacembelid fishes, I[2] stated that *Rhynchobdella aculeata* is found in great abundance in Bihar far above the tidal influence. Shaw and Shebbeare (*loc. cit.*) also made a similar observation on the authority of Mr. C. M. Inglis. The present record of the species from the Raipur District shows that fresh water is no bar to its distribution and it is likely that the fish will be found to be more widely distributed in the inland waters of India.

### **Barbus (Puntius) dorsalis** (Jerdon).

1936. *Barbus* (*Puntius*) *dorsalis*, Hora, *Rec. Ind. Mus.* XXXVIII, p. 2, text-figs. 1, 2.

In 1936, I discussed the systematic position of *Barbus dorsalis* and showed that it had been described under several names owing to colour variations during growth. Hitherto it has been found only in South India (" Kurnool, Mysore, throughout Madras as low as the Cauvery and Coleroon rivers and Ceylon ". Day), and the present record from the Raipur District considerably extends its range towards north-east. From the large number of specimens collected by Dr. Rao, it seems that the species is fairly common in the Mahanadi system.

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[1] Day, F., *Fish. India*, p. 338, pl. lxxii, fig. 1 (1876).
[2] Hora, S. L., *Trans. Nat. Inst. Sci. India*, I, p. 8 (1935

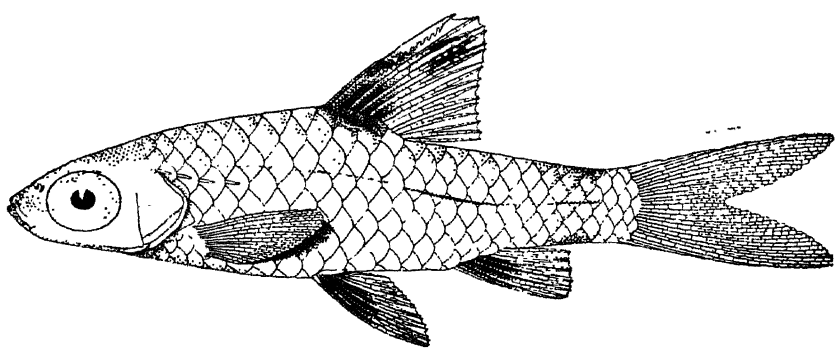
Though the specimens obtained by Dr. Rao range in total length from 30 to 74 mm., the characteristic black spots on the dorsal and anal fins are absent in all of them. The spot before the base of the caudal fin is present, being more marked in smaller specimens. The colour pattern of the scales is also indistinguishable. The dorsal spine is rather weak and articulated, and in this respect the specimens agree with the form described as *Puntius puckelli* by Day[1].

**Barbus (Puntius) gelius** Hamilton.

1878. *Barbus gelius,* Day, *Fish. India,* p. 577, pl. cxlv, fig. 3.

*Barbus gelius* is represented in the collection by three juvenile specimens. This species is liable to be confused with *Barbus phutunio,* but the two can be distinguished by their respective colour patterns. The distinguishing characters of the Indian Carp Minnows without barbels and with a serrated dorsal spine have been tabulated by Hora, Misra and Malik[2].

Hamilton's[3] *Cyprinus canius* with reddish colours has been regarded by later workers as a synonym of *Cyprinus gelius* with yellowish colours. A close study of the descriptions of the two species shows their great



TEXT-FIG. 1.—Lateral view of *Barbus* (*Puntius*) *gelius* Hamilton: $\times 3\frac{2}{3}$.

similarity, and it seems probable that the colour differences between the two are correlated with sex. From our knowledge of sexual dimorphism in allied species it may be surmised that *C. canius* represents the males and *C. gelius* the females of one and the same species.

According to Day, *B. gelius* is found in Ganjam, Orissa, Bengal and Assam. It was originally described from ponds and ditches of the north-eastern parts of Bengal.

**Barbus (Puntius) guganio** (Hamilton).

1939. *Barbus guganio,* Das, *Rec. Ind. Mus.* XLI, p. 442, text-fig. 3.

In dealing with a collection of fish from the Hazaribagh District, Das (*loc. cit.*) discussed the systematic position of *Barbus guganio* and

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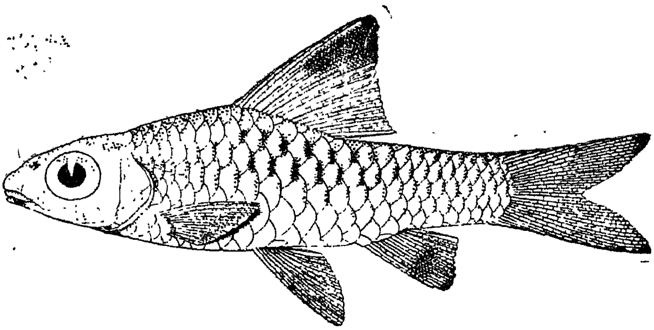
[1] Day, F., *Proc. Zool. Soc. London,* p. 197 (1868).
[2] Hora, S. L., Misra, K. S., Malik, G. M., *Rec. Ind. Mus.* XLI, p. 273 (1939).
[3] Hamilton, F., *Fish. Ganges,* p. 320 (Edinburgh, 1822).

showed that *Barbus ambassis* Day is to be regarded as its synonym. From the material collected by Dr. Rao from the Raipur District I am able to confirm the conclusions of Das. The characteristic black dorsal spine of the young specimens enables the species to be distinguished readily.

### **Oreichthys cosuatus** (Hamilton).

1822. *Cyprinus (Cabdio) cosuatus*, Hamilton, *Fish. Ganges*, p. 333.
1877. *Barbus cosuatus*, Day, *Fish. India*, p. 581, pl. cxliv, fig. 1.
1933. *Oreichthys parvus*, Smith, *Journ. Siam. Soc. Nat. Hist. Suppl.* IX, p. 63.
1937. *Barbus cosuatus*, Hora, *Rec. Ind. Mus.* XXXIX, p. 17, fig. 6.
1937. *Oreichthys cosuatus*, Hora, *Rec. Ind. Mus.* XXXIX, pp. 331-333, text-fig. 1.

*Oreichthys cosuatus* is represented in Dr. H. S. Rao's collection from the Raipur District by 5 specimens, ranging from 21 mm. to 34 mm. in total length. The precise systematic position of this interesting species was discussed by me recently, and it was indicated that the range of the species extends to Siam. Comments were also made on the variation in colouration with the growth of the fish, and on the extent of the lateral line. In the specimens under report the precaudal, anal and



TEXT-FIG. 2.—Lateral view of *Oreichthys cosuatus* (Hamilton): $\times 2\frac{2}{3}$.

dorsal spots as such are absent, but the distal portions of a few of the anterior dorsal rays are black and a number of rays are dotted with black in the middle of their lengths. The rays of the anal fin are also similarly dotted so that an indistinct band is formed across the fin. The basal portions of the scales are streaked with black, and the lateral line extends only over a few of the anterior scales. The characteristic sensory folds on the head are fairly well marked, and enable the fish to be readily distinguished from a large number of small carp-minnows in the collection.

### **Nemachilus denisonii** Day.

1939. *Nemachilus ? denisonii*, Das, *Rec. Ind. Mus.* XLI, p. 446, text-fig. 4.

In recording *Nemachilus denisonii* from the Hazaribagh District, Das was very doubtful about his identification as this species had not been found previously outside South India and the Deccan. In Dr. Rao's recent collection from the Raipur District the species is represented by a large number of young, half-grown and adult specimens. The colour

varies considerably with age, but the general pattern is fairly characteristic of the species. While in the young specimens the fins are without any markings and the body is marked with a few short bands, in the adult the bands on the body are more regular and numerous, the dorsal fin is marked with a row of spots across its middle and the caudal fin is provided with several irregular rows of spots.

**Amblyceps mangois** (Hamilton).

1939. *Amblyceps mangois*, Das, *Rec. Ind. Mus.* XLI, p. 448.

So far as the distribution of *Amblyceps mangois* in India proper is concerned it has hitherto been known from the Brahmaputra, Ganges and Indus river systems. The occurrence of the species in the Mahanadi system is, therefore, of considerable interest. Within the last few years the range of the species has been extended considerably—from the Kangra and the Raipur districts in the west to Siam and the Federated Malay States in the east.

SUMMARY.

A collection of fishes from the headwaters of the Mahanadi river is found to contain representatives of 43 well-known species. Short descriptions of localities with lists of fishes collected from each are given. Reference is made to the zoogeographical significance of the occurrence in the Raipur District of such forms as *Barbus* (*Puntius*) *dorsalis*, *Nemachilus denisonii* and *Amblyceps mangois*. Notes are given on *Rhynchobdella aculeata*, *Barbus* (*Puntius*) *dorsalis*, *B.* (*Puntius*) *gelius*, *B.* (*Puntius*) *guganio*, *Oreichthys cosuatus and Nemachilus denisonii.*

# RECORDS

of the

# INDIAN MUSEUM

**Vol. XLIII, Part II, pp. 233—256**


# The Freshwater Fish of Travancore.


By

**SUNDER LAL HORA**

**and**

**NIRMAL CHANDRA LAW**



CALCUTTA

JUNE, 1941

✓

# THE FRESHWATER FISH OF TRAVANCORE.

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(Plate IX.)

CONTENTS.



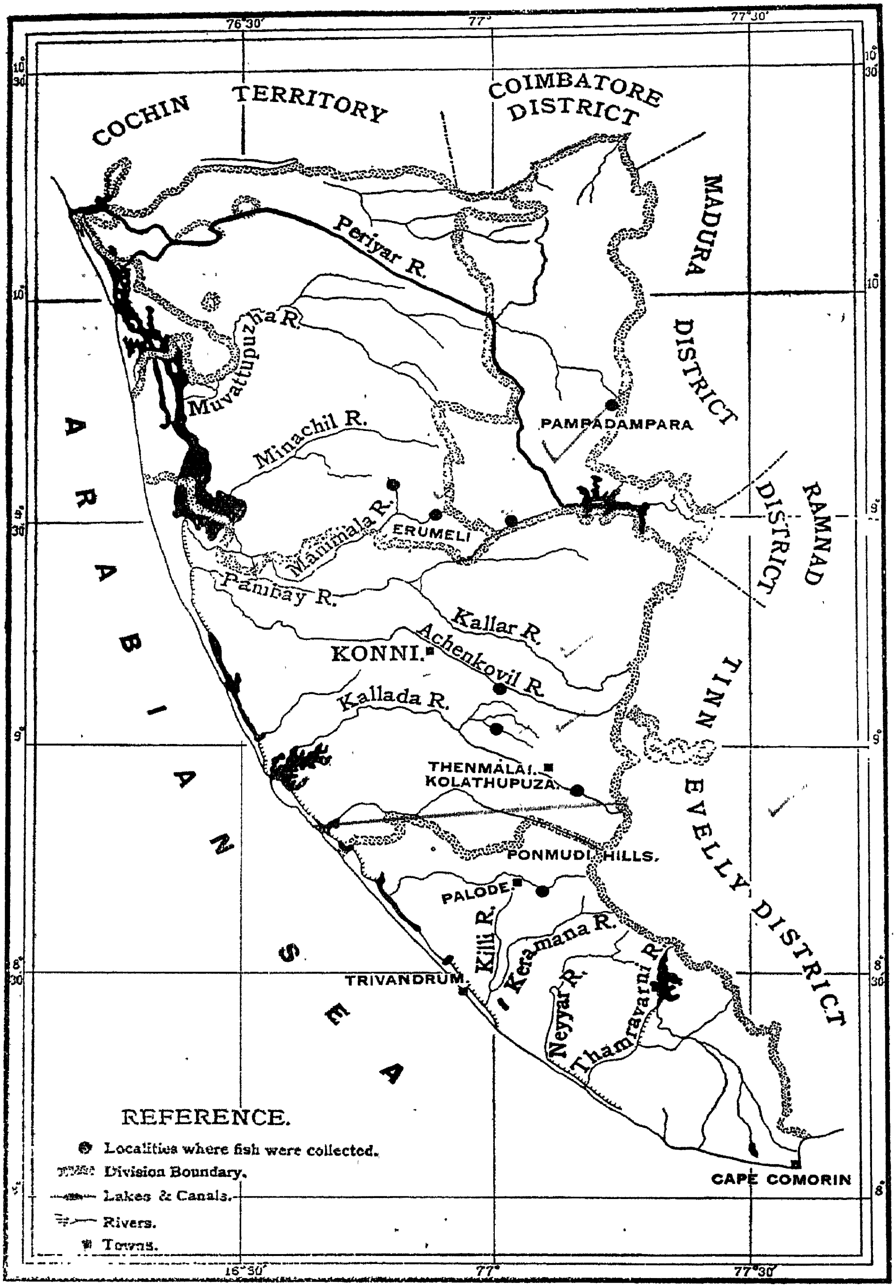
## INTRODUCTION.

The freshwater fish of Travancore are particularly interesting on account of the zoogeographical peculiarities of some of the forms. An account of the geography of the country, in so far as it affects the aquatic fauna, will be found in John's[1] account of ' Freshwater Fish and Fisheries of Travancore '. It may be well, however, to reiterate here that Travancore lies in the extreme southwest of Peninsular India between 8° 4′ and 10° 21′ N. and 76° 14′ and 77° 73′ E., and that its eastern boundary is formed by a continuous range of hills. The total area of the State is 7,625 square miles, of which 3,547 square miles comprise the up-country reaching an altitude ranging from 4,000 to 8,000 feet above sea level, 2,707 square miles comprise mid-country and the remaining 1,371 square miles constitute the low-country. The hill ranges of Travancore are in reality spurs of the Western Ghats and as they stand like a wall behind the narrow coastal plains they obstruct the south-west monsoon and in consequence the rainfall is heavy between the months of May and August. There is a certain amount of rainfall during the north-east monsoon also. The maximum annual rainfall is about 200 inches.

Owing to the mountainous character of the country and the heavy rainfall, both during the summer and winter months, there is a large number of perennial torrential streams harbouring remarkable forms adapted for life in swift currents. With a view to study the fish-fauna of such waters, one of us requested Mr. S. Jones and Dr. C. C. John to collect for the Zoological Survey of India a representative lot of hill-stream fishes from different parts of the State. They very kindly undertook the work and the collection under report was made by them from the following localities :—

1. Pampadampara Tank, North Travancore.
2. Streams within a radius of about 5 miles round Pampadampara, North Travancore.
3. Dhobikana, a small stream close to Pampadampara, North Travancore.
4. Sannyasa-ode, near Pampadampara, North Travancore.

[1] John, C. C., *Journ. Bombay Nat. Hist. Soc.* XXXVIII, pp. 702-733 (1936).




TEXT-FIG. 1.—Map of Travancore showing localities in which the fish were collected by Mr. S. Jones and Dr. C. C. John.

5. Manimala R., near Kangirappally, Central Travancore.
6. A tributary of Manimala R., Erumeli, Central Travancore.
7. Pool at the foot of the largest fall of Peruntenaruvi, a tributary of Pamba R., at Edakadathy, Central Travancore.
8. Achenkovil R., 7 miles south-east of Konni, Central Travancore.
9. Near the source of Kallada R., 4 miles east of Thenmalai, Central Travancore
10. Kulathupuzha, a tributary of Kallada R., Central Travancore.
11. Kallar stream at the foot of Ponmudi Hills, South Travancore.
12. Chittar stream at Palode, South Travancore.
13. Trivandrum, South Travancore.

With the exception of the Kallar stream, Mr. Jones's collection was made from streams in North Travancore, while Dr. John sent the material from the southern and central parts of the State. The collection under report is, therefore, fairly representative of the hill-stream fish-fauna of the State. Further search is, however, likely to reveal more forms from similar habitats. As one new genus and two new species have been found in the material collected by Mr. Jones and Dr. John there is every likelihood of more new species being found among the smaller forms that live under rocks and stones in torrential streams. Attention may also be directed to the fact that recently Raj[1] has described a new genus of Schizothoracine fishes from the Periyar Lake, Travancore.

The material is in an excellent state of preservation which shows that great care must have been taken in handling the specimens in the field. We wish to express here our great indebtedness to Mr. S. Jones and Dr. C. C. John for making the collection and presenting it to the Zoological Survey of India. A duplicate set of the material has been sent to the Government Museum, Trivandrum.

In January 1941, Dr. A. W. C. T. Herre of the Stanford University, California, visited Travancore and made a collection of fish. He presented to the Zoological Survey of India a few specimens obtained by him from the Kallar stream, 30 miles north-east of Trivandrum. The following species are represented in this lot:—

1. *Barilius gatensis* (Cuv. & Val.).
2. *Barbus* (*Puntius*) *amphibius* (Cuv. & Val.).
3. *Barbus* (*Puntius*) *melanampyx* (Day).
4. *Garra mullya* (Sykes).
5. *Bhavania australis* (Jerdon).
6. *Nemachilus triangularis* (Day).
7. *Mastacembelus armatus* (Lacép.).

The first comprehensive list of 369 species of the fishes of Travancore was published by Pillay[2], but he remarked that the list would probably be greatly augmented if the marine, brackish and fresh waters of the State could be systematically investigated. His list contains 72 freshwater species. John (*loc. cit.*) gave a list of 73 species but though he had included practically all the freshwater fishes listed by Pillay, he omitted to include, without comments, *Barilius bakeri*, *Barbus malabaricus* and *B. wynaadensis* which had already been recorded by Pillay from Travancore. However, he added to the previous list *Anguilla vulgaris*, *Barbus filamentosus*, *B. punctatus* and *B. sarana*. We have not been able to find any reference to the first of these species and presumably the author has confused his determination with the marine

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[1] Raj, B. Sundara, *Rec. Ind. Mus.* XLIII, pp. 209-214 (1941).
[2] Pillay, R. S. N., *Journ. Bombay Nat. Hist. Soc.* XXXIII, pp. 347-379 (1929).

fish *Conger vulgaris* Cuvier which is a synonym of *Conger conger* (Linn.). Leaving this species out of consideration and combining the two lists, we have in all 75 species of freshwater fishes recorded from Travancore. Of these *Barbus filamentosus* and *B. mahecola* are synonymous[1] as they represent male and female sexes respectively of the same species (*vide infra*, p. 245). Similarly, *Haplochilus lineatus* and *H. rubrostigma* represent the two sexes of the same species. One of us[2] has shown that *Callichrous malabaricus* is a synonym of *C. bimaculatus*. *Rasbora nilgheriensis*, as noted by Day,[3] is only a colour variety of the widely distributed *R. daniconius*. Thus the total number of freshwater species is reduced to 71. Of these, *Megalops cyprinoides*, *Hemirhamphus xanthopterus*, *Ambassis gymnocephalus*, *Gerres limbatus* and *Gobius striatus* (=*Awaous stamineus*) are mainly marine and brackish water species, though they may frequent fresh waters also. For this reason, it is advisable to exclude them from a list of purely freshwater fishes, the number of which will thus be reduced to 66.

We[4] have described from Dr. John's collection a new Catfish, *Batasio travancoria*, from Central and Southern Travancore, while Raj[5] has more recently described a small-scaled Barbel, *Lepidopygopsis typus*, from the Periyar Lake, and Hora[6] has described from Mr. Jones's collection a Homalopterid loach, *Travancoria jonesi*, from Northern Travancore. Among the material under report we have further found representatives of the following species which were not recorded by Pillay and John : *Barilius gatensis*, *Danio aequipinnatus*, *Rasbora rasbora*, *Barbus mussullah*, *Barbus ticto*, *Garra mullya*, *Lepidocephalus thermalis*, *Nemachilus evezardi*, *N. guentheri*, *Bhavania australis*, *Mystus cavasius* and *Glyptothorax madraspatanus*. Of these, *B. mussullah* probably corresponds to *B. tor* of the lists of Pillay and John ; *D. aequipinnatus* to *D. malabaricus* ; *B. ticto* to *B. punctatus* ; *G. mullya* to *Discoganthus lamta* and *B. australis* to *Homaloptera maculata*. Thus, excluding these five species, only 7 additional species are added to the list as a result of our present study. The total number of species now known from the fresh waters of Travancore is 76. As the nomenclature of a number of species is changed, we give below a complete systematic list of the freshwater fishes of Travancore with their up-to-date scientific names and geographical range. For vernacular names reference may be made to the lists published by Pillay and John respectively.

## List of the Freshwater Fish of Travancore with their Geographical Range.

The general classification of fishes adopted in the list is that proposed by Dr. C. Tate Regan, F.R.S., in his article on ' Fishes ' in the Fourteenth Edition of the *Encyclopaedia Britannica* (1929). The genera under their respective families and the species under each genus are alpha-

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[1] Hora, S. L., *Rec. Ind. Mus.* XXXIX, p. 22 (1937).
[2] Hora, S. L., *Rec. Ind. Mus.* XXXVIII, pp. 356-361 (1936).
[3] Day, F., *Fish. India*, p. 584 (1878).
[4] Hora, S. L., and Law N. C., *Rec. Ind. Mus.* XLIII, pp. 40-42 (1941).
[5] Raj, B. Sundara, *Rec. Ind. Mus.* XLIII, p. 209 (1941).
[6] Hora, S. L., *Rec. Ind. Mus.* XLIII, p. 230 (1941).

betically arranged. The species whose name is marked with an asterisk (*) is represented in the collection under report.

| List of Species. | Geographical Range. |
| --- | --- |
| Order : OSTARIOPHYSI. | |
| Suborder : *CYPRINOIDEA.* | |
| Family : CYPRINIDAE. | |
| Subfamily: *ABRAMADINAE.* | |
| 1. *Chela boopis* Day .. .. | Travancore and South Canara. |
| 2. *Laubuca laubuca* (Ham.) .. | Ceylon, India, Burma and Sumatra. |
| Subfamily : *RASBORINAE.* | |
| 3. *Barilius bakeri* Day .. .. | Travancore. |
| *4. *Barilius gatensis* (C. V.) .. | Western Ghats, Nilgiris and Coorg |
| *5. *Danio aequipinnatus* (McClell.) .. | Ceylon, India, Burma and Siam. |
| *6. *Rasbora daniconius* (Ham.) .. | Ceylon, India, Burma, Siam, Malaya etc. |
| *7. *Rasbora rasbora* (Ham.) .. | India, Burma, Siam and Malaya. |
| Subfamily : *CYPRININAE.* | |
| 8. *Amblypharyngodon melettina* (C. V.) | Ceylon, Peninsular India and Deccan |
| 9. *Amblypharyngodon microlepis* (Blkr.) | Peninsular India, through Orissa to Hooghly. |
| 10. *Amblypharyngodon mola* (Ham.) .. | India and Burma. |
| *11. *Barbus (Puntius) amphibius* (C. V.) | Ceylon and Peninsular India. |
| 12. *Barbus (Puntius) arulius* (Jerd.) .. | Peninsular India. |
| 13. *Barbus (Puntius) burmanicus* (Day) | Travancore, Burma and Malaya. |
| 14. *Barbus (Puntius) conchonius* Ham. | India (generally Northern India). |
| *15. *Barbus (Puntius) curmuca* (Ham.) | Western Ghats. |
| 16. *Barbus (Puntius) denisoni* (Day) | Travancore. |
| *17. *Barbus (Puntius) filamentosus* (C. V.) | Ceylon and Peninsular India. |
| 18. *Barbus (Puntius) lithopidos* Day | Travancore, South Canara and Coorg. |
| 19. *Barbus (Tor) malabaricus* Jerd. | Travancore and South Canara. |
| *20. *Barbus (Puntius) melanampyx* (Day) | Peninsular India. |
| 21. *Barbus (Puntius) melanostigma* (Day) .. .. .. | Travancore, Wynaad and Nilgiris. |
| *22. *Barbus (Tor) mussullah* Sykes .. | Peninsular India, and Deccan. |
| 23. *Barbus (Puntius) parrah* (Day) .. | Peninsular India. |
| *24. *Barbus (Puntius) pinnauratus* (Day) .. .. .. | Ceylon, Peninsular India, Satpuras, Burma and Siam. |
| 25. *Barbus (Puntius) sarana* (Ham.) .. | India and Burma. |
| 26. *Barbus (Puntius) sophore* Ham.[1] | India, Burma and Yunnan. |
| *27. *Barbus (Puntius) ticto* Ham. .. | Ceylon, India, Burma and Siam. |
| 28. *Barbus (Puntius) vittatus* (Day) .. | Ceylon, Peninsular India and Cutch. |
| 29. *Barbus (Puntius) wynaadensis* Day | Travancore and Wynaad. |
| 30. *Garra jerdoni* (Day) .. .. | Peninsular India. |
| *31. *Garra mullya* (Sykes) .. | Peninsular India, Satpuras and Kathiawar. |
| 32. *Labeo dussumieri* (C. V.) .. | Ceylon, Peninsular India and Gujarat. |
| 33. *Rohtee bakeri* Day .. .. | Travancore. |
| Subfamily : *SCHIZOTHORACINAE.* | |
| 34. *Lepidopygopsis typus* Raj. .. | Travancore. |

[1] This is the same species as *Barbus stigma* (Cuv. & Val.) of the earlier lists. For nomenclatorial change see Chaudhuri, *Mem. Ind. Mus.* V, p. 436 (1916).

| List of Species. | Geographical Range. |
|---|---|
| Family : HOMALOPTERIDAE. | |
| Subfamily: *HOMALOPTERINAE.* | |
| *35. *Bhavania australis* (Jerd.) | Travancore, Nilgiris, Wynaad and Mysore. |
| *36. *Travancoria jonesi* Hora | Travancore. |
| Family : COBITIDAE. | |
| *37. *Lepidocephalus thermalis* (C. V.) .. | Ceylon and Peninsular India. |
| 38. *Nemachilus botia* (Ham.) .. | Ceylon, India and Burma. |
| *39. *Nemachilus evezardi* Day .. | Peninsular India and Deccan. |
| *40. *Nemachilus guentheri* Day .. | Travancore and Nilgiri Hills. |
| *41. *Nemachilus triangularis* Day .. | Travancore. |
| Suborder : *SILUROIDEA.* | |
| Family : CLARIIDAE. | |
| 42. *Clarias batrachus* (Linn.) .. | India, Burma, Siam, Malaya and further east. |
| Family : HETEROPNEUSTIDAE. | |
| 43. *Heteropneustes fossilis* (Bloch) .. | Ceylon, India, Burma, Siam and Cochin-China. |
| Family : SILURIDAE. | |
| *44. *Callichrous bimaculatus* (Bloch) .. | Ceylon, India, Burma and further east. |
| 45. *Wallagonia attu* (Bloch) .. | Ceylon, India, Burma, Siam, Malay Peninsula and Western Yunnan. |
| Family : SCHILBEIDAE. | |
| 46. *Pseudeutropius sykesi* (Jerd.) .. | Peninsular India. |
| Family : BAGRIDAE. | |
| *47. *Batasio travancoria* Hora & Law .. | Travancore. |
| *48. *Mystus cavasius* (Ham.) .. | India, Burma and Siam. |
| 49. *Mystus chryseus* (Day) .. | Travancore, Canara and Malabar. |
| 50. *Mystus gulio* (Ham.) .. .. | Ceylon, India, Burma and Malaya. |
| *51. *Mystus malabaricus* (Jerd.) .. | Travancore, Malabar and Wynaad. |
| 52. *Mystus montanus* (Jerd.) .. | Travancore, Wynaad and Cauvery R. |
| 53. *Mystus oculatus* (C. V.) .. | Travancore, Malabar and Nilgiris. |
| 54. *Mystus vittatus* (Bloch) .. | Ceylon, India, Burma and Siam. |
| Family : SISORIDAE. | |
| *55. *Glyptothorax madraspatanus* (Day) | Travancore, Nilgiris, and Mysore. |
| Order : APODES. | |
| Family : ANGUILLIDAE. | |
| 56. *Anguilla bicolor* McClelland .. | Africa, India and further east. |
| Order : SYNENTOGNATHI. | |
| Suborder : *SCOMBRESOCOIDEA.* | |
| Family : XENENTODONTIDAE or BELONIDAE | |
| *57. *Xenentodon cancila* (Ham.) .. | Ceylon, India, Burma, Malaya and Siam. |
| Order : MICROCYPRINI. | |
| Family : CYPRINODONTIDAE. | |
| 58. *Aplochilus lineatus* (C. V.) .. | Ceylon, Peninsular India and Deccan. |
| Order : PERCOMORPHI. | |
| Suborder : *PERCOIDEA.* | |
| Family : AMBASSIDAE. | |
| 59. *Ambassis dayi* Blkr. .. .. | Travancore and Malabar. |
| 60. *Ambassis nalua* (Ham.) | Travancore, Malabar, Calcutta, Andamans and Malay Archipelago. |
| 61. *Ambassis thomassi* Day | Travancore, Malabar, Siam and Malaya. |

| List of Species. | Geographical Range. |
|---|---|
| Family: NANDIDAE. | |
| 62. *Nandus nandus* (Ham.) .. | India, Burma, Siam and Malaya. |
| Family: PRISTOLEPIDAE. | |
| 63. *Pristolepis fasciata* (Blkr.) .. | Travancore, Burma, Siam, Malay Archipelago and Cochin-China. |
| 64. *Pristolepis malabarica* (Gthr.) .. | Southern part of Western Ghats. |
| Family: CICHLIDAE. | |
| 65. *Etroplus maculatus* (Bloch) .. | Ceylon and Peninsular India. |
| 66. *Etroplus suratensis* (Bloch) .. | Ceylon, Peninsular India and Deccan. |
| Suborder: *GOBIOIDEA.* | |
| Family: GOBIIDAE. | |
| 67. *Glossogobius giuris* (Ham.) .. | Ceylon, India, Burma and further east. |
| Suborder: *ANABANTOIDEA.* | |
| Family: ANABANTIDAE. | |
| 68. *Anabus testudineus* (Bloch) .. | Ceylon, India, Burma and further east. |
| Family: POLYCANTHIDAE. | |
| 69. *Macropodus cupanus* C. V. .. | South India, Malay Peninsula and Sumatra. |
| Suborder: *OPHICEPHALOIDEA.* | |
| Family: OPHICEPHALIDAE. | |
| *70. *Ophicephalus gachua* Ham. .. | Ceylon, India, Burma and further east. |
| 71. *Ophicephalus leucopunctatus* Sykes | Peninsular India and Deccan. |
| 72. *Ophicephalus marulius* Ham. .. | Ceylon, India, Burma to China. |
| 73. *Ophicephalus micropeltes* (K. & V. Hass.) C. V. .. .. | Western Coast of India, Malay Archipelago, Siam and Indo-China. |
| 74. *Ophicephalus striatus* Bloch .. | Ceylon, India, Burma and further east. |
| Order: OPISTHOMI. | |
| Family: MASTACEMBELIDAE. | |
| *75. *Mastacembelus armatus* (Lacép.) .. | Ceylon, India, Burma and further east. |
| 76. *Mastacembelus guentheri* Day .. | Travancore, Malabar and Malaya. |

As is to be expected, a great majority of the species belong to the Ostariophysi, 41 to the Suborder Cyprinoidea and 14 to the Suborder Siluroidea. Of the remaining 21 species, 1 belongs to Apodes (Anguillidae), 1 to Synentognathi (Belonidae), 1 to Microcyprini (Cyprinodontidae), 16 to Percomorphi (Ambassidae 3; Nandidae 1; Pristolepidae 2; Cichlidae 2; Gobiidae 1; Anabantidae 1; Polycanthidae 1; Ophicephalidae 5) and 2 to Opisthomi (Mastacembelidae).

## ZOOGEOGRAPHICAL REMARKS.

With the exception of the Cichlidae, which are confined to Peninsular India and Ceylon, the remaining families listed above are widely distributed in the Oriental Region and even further afield. The Cichlidae represent the Ethiopean element in the fish-fauna of India[1]. The Schizothoracinae, which are the dominant fish of the streams, marshes and lakes of the high plateau of Central Asia, represent the Palaearctic

[1] Hora, S. L., *Curr. Sci.* V, p. 354 (1937).

element in the fauna of Peninsular India. Two genera of the Schizothoracinae, *Schizothorax* Heckel and *Oreinus* McClelland, are found in torrential streams along the southern slopes of the Himalayas, but nowhere else in India. The occurrence of *Lepidopygopsis* in the Periyar Lake is, therefore, of special zoogeographical significance. Similarly the Homalopteridae, which are represented in Travancore by two genera of the Homalopterinae are of particular interest. The Homalopteridae are represented by a number of genera in south-eastern Asia and in India proper their range extends up to the hill ranges of Assam and Chittagong, and the Eastern Himalayas ; they are absent from the rest of India with the exception of the southern parts of the Western Ghats. The same can be said with regard to the distribution of *Batasio* Blyth. The genera *Macropodus* Lacépède and *Pristolepis* Jerdon are either found in Peninsular India or in the Far East. There are species in the fauna of Travancore, such as *Mastacembelus guentheri*, *Barbus* (*Puntius*) *burmanicus*, *Ambassis thomassi*, and *Ophicephalus micropeltes*, which show a similar discontinuity in the respective ranges of their distribution. Even if individuals of a single species are considered, we find that specimens of *Barbus* (*Puntius*) *ticto* with the lateral line complete are either found in Peninsular India or in Burma and Siam. There is thus a great deal of evidence to show the close relationship of the Malayan fauna with that of Peninsular India.

The freshwater fish-fauna of Travancore can be divided into the following groups from a zoogeographical point of view :

Group I.—*Species distributed throughout India, Burma and further east.*

1. *Laubuca laubuca* (Ham.).
2. *Danio aequipinnatus* (McClell.).
3. *Rasbora daniconius* (Ham.).
4. *Rasbora rasbora* (Ham.).
5. *Amblypharyngodon mola* (Ham.).
6. *Barbus* (*Puntius*) *pinnauratus* (Day).
7. *Barbus* (*Puntius*) *sarana* (Ham.).
8. *Barbus* (*Puntius*) *sophore* Ham.
9. *Barbus* (*Puntius*) *ticto* Ham.
10. *Nemachilus botia* (Ham.).
11. *Clarias batrachus* (Linn.).
12. *Heteropneustes fossilis* (Bloch).
13. *Callichrous bimaculatus* (Bloch).
14. *Wallagonia attu* (Bloch).
15. *Mystus cavasius* (Ham.).
16. *Mystus gulio* (Ham.).
17. *Mystus vittatus* (Bloch).
18. *Anguilla bicolor* McClell.
19. *Xenentodon cancila* (Ham.).
20. *Ambassis nalua* (Ham.).
21. *Nandus nandus* (Ham.).
22. *Anabas testudineus* (Bloch).
23. *Glossogobius giuris* (Ham.).
24. *Ophicephalus gachua* Ham.
25. *Ophicephalus marulius* Ham.
26. *Ophicephalus striatus* Bloch.
27. *Mastacembelus armatus* (Lacép.).

Group II.—*Species distributed in Peninsular India, Malay Peninsula etc.*

1. *Barbus* (*Puntius*) *burmanicus* Day.
2. *Ambassis thomassi* Day.
3. *Ophicephalus micropeltes* C. V.
4. *Pristolepis fasciata* (Blkr.).
5. *Macropodus cupanus* C. V.
6. *Mastacembelus guentheri* Day.

Group III.—*Species distributed throughout India.*

1. *Barbus* (*Puntius*) *conchonius* Ham.

### Group IV.—*Species with restricted distribution in India.*

1. *Amblypharyngodon microlepis* (Blkr.).
2. *Barbus (Tor) mussullah* Sykes.
3. *Garra mullya* (Sykes).
4. *Nemachilus evezardi* Day.

### Group V.—*Species common to Peninsular India and Ceylon.*

1. *Amblypharyngodon melettina* (C. V.).
2. *Barbus (Puntius) amphibius* (C. V.).
3. *Barbus (Puntius) filamentosus* (C. V.).
4. *Barbus (Puntius) vittatus* (Day).
5. *Labeo dussumieri* (C. V.).
6. *Lepidocephalus thermalis* (C. V.).
7. *Aplochilus lineatus* (C. V.).
8. *Etroplus maculatus* (Bloch).
9. *Etroplus suratensis* (Bloch).

### Group VI.—*Species distributed throughout Peninsular India.*

1. *Barbus (Puntius) arulius* (Jerd.).
2. *Barbus (Puntius) melanampyx* (Day).
3. *Barbus (Puntius) parrah* (Day).
4. *Garra jerdoni* (Day).
5. *Pseudeutropius sykesi* (Jerd.).
6. *Ophicephalus leucopunctatus* Sykes.

### Group VII.—*Species found in the Western Ghats and associated hills.*

1. *Chela boopis* Day.
2. *Barilius gatensis* (C. V.).
3. *Barbus (Puntius) curmuca* (Ham.).
4. *Barbus (Puntius) lithopidos* Day.
5. *Barbus (Tor) malabaricus* Jerd.
6. *Barbus (Puntius) melanostigma* (Day).
7. *Barbus (Puntius) wynaadensis* Day.
8. *Bhavania australis* (Jerd.).
9. *Nemachilus guentheri* Day.
10. *Mystus chryseus* (Day).
11. *Mystus malabaricus* (Jerd.).
12. *Mystus montanus* (Jerd.).
13. *Mystus oculatus* (C. V.).
14. *Glyptothorax madraspatanus* (Day).
15. *Ambassis dayi* Blkr.
16. *Pristolepis malabarica* (Gthr.).

### Group VIII.—*Species endemic in Travancore.*

1. *Barilius bakeri* Day.
2. *Barbus (Puntius) denisoni* Day.
3. *Rohtee bakeri* Day.
4. *Lepidopygopsis typus* Raj.
5. *Travancoria jonesi* Hora.
6. *Nemachilus triangularis* Day.
7. *Batasio travancoria* Hora & Law.

Of the 76 species listed above, 27 are widely distributed in India, Burma and further east ; 6 are found in Peninsular India on the one hand and in Burma and further east on the other, but nowhere else in India ; 1 is distributed all over India proper but is not found in Burma ; 4 have a restricted distribution in India, mainly in Peninsular India and along the Satpura Trend of mountains ; 9 are found in Peninsular India and Ceylon, while the remaining 29 are restricted to Peninsular India and of these 7 are endemic in Travancore. Of the 29 species only known from Peninsular India, as many as 23 are found only in the Western Ghats and the associated hills. If Ceylon and Peninsular India be regarded as one zoogeographical region and the forms, which are found either in Peninsular India or further east but not in other parts of India, be grouped along with the species restricted to Ceylon and Peninsular India, it becomes apparent that about 60 per cent of the species are peculiar to Southern India and are found nowhere else in India proper. This high endemicity of the fauna of this region has been noticed by previous workers also in the case of other groups of animals.

From a zoogeographical point of view, the freshwater fish-fauna of Travancore presents two special features, the marked Malayan element

and the preponderance of endemic forms. The former, according to Blanford[1], dates in India from the Miocene times. We have indicated above the occurrence of the Homalopteridae and of the genus *Batasio* in the hills of Assam and the Eastern Himalayas which indicates the probable route along which the Malayan fauna migrated to Peninsular India. Regarding the Himalayan fauna, Blanford stated that:

"....The Indo-Malay element in the fauna is very richly represented in the Eastern Himalayas, and gradually diminishes to the westward, until in Kashmir and further west it ceases to be the principal constituent. Almost all the Indo-Malay genera, and a very large proportion of the species, are identical with Assamese or Burmese forms. These facts are consistent with the theory that the Indo-Malay part of the Himalayan fauna, or the greater portion of it, has migrated into the mountains from the eastward at a comparatively recent period. *It is an important fact that this migration appears to have been from Assam and not from the Peninsula of India.*" (Italics are ours.)

One of us[2] has explained the presence of the Indo-Malayan element in the fauna of the Eastern Himalayas and Peninsular India by postulating that the uplift movement of the Himalayas was probably most active in the region of the Assam Himalayas as practically all the highest peaks are clustered round this area. It was argued that

"This differential movement, which probably occurred late in the Miocene period, must have obliterated all traces of the eastward extension of the Indobrahm and also acted as a barrier between the eastern and western Himalayan fishes. The new stocks of specialised hill-stream fishes from the east, not finding means to cross this barrier, were deflected towards south-west along the Satpura Trend which probably at this period stretched across India as a pronounced range from Gujarat to the Assam Himalayas. From Gujarat the hill-stream fauna migrated towards the south along the Western Ghats and spread to the hills of the Peninsula in the extreme south."

To account for the anomalies of distribution referred to above, Blanford (*loc. cit.*, p. 435) postulated the diminution of temperature as the cause for the dispersal of animals from the north to the south and stated:

"....Unless the temperature of India and Burma generally underwent a considerable diminution, it is not easy to understand how plants and animals of temperate Himalayan types succeeded in reaching the hills of Southern India and Ceylon, as well as those of Burma and Malay Peninsula."

Temperature is undoubtedly a great factor in the dispersal of animals and probably has very great influence on the terrestrial fauna but in the case of aquatic animals the presence of water connections is also an important factor. Moreover, in the case of torrential fishes, such as the Homalopteridae, a rocky substratum and a swift current are also essential for their very existence. In view of these ecological considerations, it seems probable that the Satpura Trend may have acted as a highway for the migration of this fauna from the late Miocene period to the time of formation of the Rajmahal-Garro Hill gap. This movement may have been facilitated by the diminution of temperature if the earth movements of the glacial period provided necessary water connections for the transference of the fauna from the north-east to the south-west.

The high endemicity of the Travancore fauna is an evidence of its antiquity and long isolation from the fauna of the mainland of India and of the adjacent countries. After migrating from north-east to

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[1] Blanford, W. T., *Phil. Trans. Roy. Soc. London* (B) CXCIV, pp. 433, 434 (1921).
[2] Hora, S. L., *Rec. Ind. Mus.* XXXIX, p. 255 (1937).

south-west, the fauna came to a blind end in the Peninsular region and when, with the formation of the Rajmahal-Garo Hill gap and due to other causes, it became isolated, it had sufficient time to blossom out into distinct species, while still retaining its family affinities with the parent stock.

## SYSTEMATIC ACCOUNT.

### **Barilius gatensis** (Cuv. & Val.).

1878. *Barilius gatensis*, Day, *Fish. India*, p. 592, pl. cxlix, fig. 2.

4 specimens, 52 to 108 mm. in length. Streams within a radius of about 5 miles of Pampadampara, Western Ghats, North Travancore. S. Jones, April 1941.

3 specimens, 30 to 39 mm. in length. Manimala R., near Kangirappally, Central Travancore. C. C. John, 26. iii.1940.

2 specimens, 78 and 97 mm. in length respectively. Pool at the foot of the largest fall of Peruntenaruvi, a tributary of Pamba R., at Edakadathy, Central Travancore. C. C. John, 11. ii.1940.

1 specimen, 72 mm. long. Chittar stream at Palode, South Travancore. C. C. John, 10.ii.1940.

According to Day, *Barilius gatensis* is known from "Western Ghats of Malabar and Neilgherry hills", but since then its range has been extended to other parts of the Western Ghats also. In some of the specimens under report, the lateral bars are short and form a series of oblong spots along the sides. On the whole it is a brightly coloured species.

### **Danio aequipinnatus** (McClelland).

1878. *Danio aequipinnatus*, Day, *Fish. India*, p. 596, pl. cl, fig. 6.

19 specimens, 28 to 101 mm. in length. Streams within a radius of about 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, 12.iv.1940 and April 1941.

2 specimens, 45 and 80 mm. in length. Sannyasa-ode, near Pampadampara, Western Ghats, North Travancore. S. Jones, April 1940.

2 specimens, 44 and 59 mm. in length. Manimala R., near Kangirappally, Central Travancore. C. C. John, 26.iii.1940.

2 specimens, 68 and 75 mm. in length. A tributary of Manimala R., Erumeli, Central Travancore. C. C. John, 20.ii.1940.

1 specimen, 91 mm. long. Pool at the foot of the largest fall of Peruntenaruvi, a tributary of Pamba R., at Edakadathy, Central Travancore. C. C. John, 11.ii.1940.

19 specimens, 18 to 74 mm. in length. Achenkovil R., 7 miles south-east of Konni, Central Travancore. C. C. John, 17.ii.1940.

2 specimens, 66 and 68 mm. in length. Kulathupuzha, a tributary of Kallada R., Central Travancore. (Collected from a pond-like accumulation of water surrounded by big boulders.) C. C. John, 14.ii.1940.

3 specimens, 46 to 67 mm. in length. Chittar stream at Palode, South Travancore. C. C. John, 9.ii.1940.

The large number of young, half-grown and adult specimens referred by us to *Danio aequipinnatus* show variation in colouration and scale counts. It seems to us probable that *D. malabaricus* (Jerdon) of Peninsular India and Ceylon, and *D. strigillifer* Myers of North Burma and Peninsular India are synonymous with the North Indian *D. aequipinnatus*. The three forms, as known at present, are rather difficult to distinguish from one another and the material under report helps to bridge over the differences between them.

### Rasbora daniconius (Ham.).

1878. *Rasbora daniconius*, Day, *Fish. India*, P. 584, pl. cxlvi, figs. 2, 3.

7 specimens, 33 to 82 mm. in standard length. Pampadampara Tank, Western Ghats, North Travancore. S. Jones, September 1938 and March 1940.

42 specimens, 21 to 102 mm. in length. Streams within a radius of about 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, 12.iv.1940, and April 1941.

2 specimens, longer one 78 mm. in length. Manimala R., near Kangirappally, Central Travancore. C. C. John, 26.iii.1940.

The specimens of *Rasbora daniconius* correspond with Day's variety *neilgherriensis* which is stated to grow to a large size and to possess 34 scales along the lateral line. In all the specimens the lateral band is broad and well marked.

### Rasbora rasbora (Ham.).

1878. *Rasbora buchanani*, Day, *Fish. India*, p. 584, pl. cxlv, fig. 10.

2 specimens, 77 and 83 mm. in length. Streams within a radius of about 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, April 1941.

2 specimens, 50 and 65 mm. A tributary of Manimala R., Erumeli, Central Travancore. C. C. John, 20.ii.1940.

2 specimens, 82 and 94 mm. in length. Kulathupuzha, a tributary of Kallada R., Central Travancore. (Collected from a pond-like accumulation of water surrounded by big boulders.) C. C. John, 14.ii.1940.

1 specimen, 84 mm. long. Chittar stream at Palode, South Travancore. C. C. John, 10.ii.1940.

*Rasbora rasbora* is represented by a number of badly preserved specimens in which the scales have fallen off. The species is widely distributed in India and Burma, though in the fauna of South India it is less common than *R. daniconius*.

### Barbus (Puntius) amphibius (Cuv. & Val.).

1878. *Barbus amphibius*, Day, *Fish. India*, p. 574, pl. cxlii, fig. 8.

2 specimens, 36 and 77 mm. in length. Manimala R., near Kangirappally, Central Travancore. C. C. John, 26.iii.1940.

8 specimens, 62 to 70 mm. in length. A tributary of Manimala R., Erumeli, Central Travancore. C. C. John, 20.ii.1940.

1 specimen, 88 mm. long. Pool at the foot of the largest fall of Peruntenaruvi, a tributary of Pamba R., at Edakadathy, Central Travancore. C. C. John, 11.ii.1940.

3 specimens, 60 to 80 mm. in length. Near the source of Kallada R., 4 miles east of Thenmalai, Central Travancore. C. C. John, 9.ii. 1940.

4 specimens, 57 to 74 mm. in length. Kulathupuzha, a tributary of Kallada R., Central Travancore. (Collected from a pond-like accumulation of water surrounded by big boulders.) C. C. John, 14.ii.1940.

4 specimens, 59 to 70 mm. in length. Chittar stream at Palode, South Travancore. C. C. John, 10.ii.1940.

All the specimens of *Barbus amphibius* listed above are characterised by the possession of a large, well-marked black spot before the base of the caudal fin; in this respect they agree with Day's description of the Malabar examples. According to Day, this species is found in "Central India, Deccan, Bombay and the Western coast of India, Madras and up to the coast as high as Orissa."

*B. amphibius* is liable to be confused with *B. dorsalis*[1] but the prominent caudal spot and the absence of dorsal and anal spots in *B. amphibius* enable the two species to be distinguished from each other.

### **Barbus (Puntius) curmuca** (Hamilton).

(Plate IX, fig. 1.)

1878. *Barbus curmuca*, Day, *Fish. India*, p. 566, pl. cxli, fig. 1.

3 specimens, 37 to 97 mm. in length. A tributary of Manimala R., Erumeli, Central Travancore. C. C. John, 20.ii.1940.

1 specimen, 148 mm. long. Pool at the foot of the largest fall of Peruntenaruvi, a tributary of Pamba R., at Edakadathy, Central Travancore. C. C. John, 11.ii.1940.

3 specimens, 89 to 110 mm. in length. Near the source of Kallada R., 4 miles east of Thenmalai, Central Travancore. C. C. John, 9.ii.1940.

2 specimens, 106 and 113 mm. in length. Kulathupuzha, a tributary of Kallada R., Central Travancore. (Collected from a pond-like accumulation of water surrounded by big boulders.) C. C. John, 14.ii.1940.

*Barbus curmuca* is represented in the collection by a number of young, and half-grown specimens. In the largest example under report, the tips of the caudal fin are deep black in colour and proximal to them there are areas of a light colour. The rest of the fin is somewhat grayish. There is a deep black bar behind the gill-opening and in the dorsal half of the body the scales are grayish with lighter margins. The bases of the scales above and below the lateral line are provided with dark spots. The ventral surface is pale olivaceous.

### **Barbus (Puntius) filamentosus** (Cuv. & Val.).

1937. *Barbus filamentosus*, Hora, *Rec. Ind. Mus.* XXXIX, pp. 22-24, text-figs. 8, 9.

6 specimens, 65 to 87 mm. in length. A tributary of Manimala R., Erumeli, Central Travancore. C. C. John, 20.ii.1940.

12 specimens, 77 to 109 mm. in length. Pool at the foot of the largest fall of Peruntenaruvi, a tributary of Pamba R., at Edakadathy, Central Travancore. C. C. John, 11.ii.1940.

4 specimens, 63 to 84 mm. in length. Near the source of Kallada R., 4 miles east of Thenmalai, Central Travancore. C. C. John, 9.ii.1940.

3 specimens, 75 to 128 mm. in length. Kulathupuzha, a tributary of Kallada R., Central Travancore. C. C. John, 20.ii.1940.

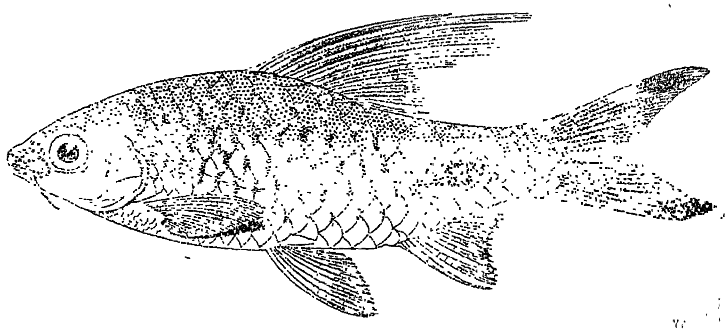
4 specimens, 70 to 82 mm. in length. Chittar stream at Palode, South Travancore. C. C. John, 10.ii.1940.

Of the 29 specimens of *Barbus filamentosus* collected by Dr. C. C. John from different localities in Travancore as listed above, there are only 6 fully developed males while the remaining examples are either females or juveniles. In the males the number of prolonged filiform rays varies from 3 to 5 and in one specimen the last unbranched ray is also greatly elongated (text-fig. 2). All the males are provided with patches of large tubercles on either side of the snout. These secondary sexual characters are very characteristic features of the species.

As already pointed out by one of us, considerable importance has been attached to the presence or absence of barbels in the individuals of this species. Small barbels, sometimes hidden in the grooves round

[1] Hora, S. L., *Rec. Ind. Mus.* XXXVIII, pp. 2-5 (1936).

the corners of the mouth, are invariably present in all the specimens, but they seem to vary considerably in length. In smaller individuals



TEXT-FIG. 2.—Lateral view of a mature male specimen of *Barbus* (*Puntius*) *filamentosus* (Cuv. & Val.), showing secondary sexual characters. *Nat. Size.*

they are relatively larger. In one of the male specimens (text-fig. 2) the barbels extend as far back as the posterior border of the eye. In one of the female specimens also the barbels are of the same length, while in two others they extend up to the middle of the eye. One specimen is still more remarkable, for in it the barbel of one side reaches the posterior border of the orbit while that of the other side is very small.

The colour varies considerably with age. In the young specimens the colour marks are not so prominent; the large lateral blotch is, however, fairly well marked and the fins are somewhat dusky. Some of the outer rays of the caudal fin in both the lobes are dark in colour. The bases of the scales are also faintly marked with dark spots. In larger specimens the lateral blotches as also the caudal blotches are intensely black and are surrounded by whitish areas. The black spots at the bases of the scales become somewhat darker, and in males (text-fig. 2) these markings become very prominent. Usually in the males a dark mark is also present behind the gill-opening. The last undivided ray is white in the males and the filamentous prolongations of the rays are somewhat dusky.

*Barbus filamentosus* is a South Indian species, having been recorded so far from " Canara down the Western coast and along the base of the Neilgherries, and Travancore hills, also Ceylon." It is said to attain at least 6 inches in length.

### Barbus (Puntius) melanampyx (Day).

1938. *Barbus melanampyx*, Misra, *Rec. Ind. Mus.* XL, pp. 258-260, 1 text-fig.

30 specimens, 23 to 57 mm. in length. Pampadampara Tank, Western Ghats, North Travancore. S. Jones, September 1938 and March 1940.

52 specimens, 19 to 64 mm. in length. Streams within a radius of about 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, 12.iv.1940 and April 1941.

4 specimens, 21 to 37 mm. in length. Manimala R., near Kangirappally, Central Travancore. C. C. John, 26.iii.1940.

1 specimen, 52 mm. long. A tributary of Manimala R., Erumeli, Central Travancore. C. C. John, 20.ii.1940.

20 specimens, 22 to 45 mm. in length. Achenkovil R., 7 miles south-east of Konni, Central Travancore. C. C. John, 17.ii.1940.
1 specimen, 58 mm. long. Kulathupuzha, a tributary of Kallada R., Central Travancore. (Collected from a pond-like accumulation of water surrounded by big boulders.) C. C. John, 14.ii.1940.
6 specimens, 25 to 57 mm. in length. Chittar stream at Palode, South Travancore. C. C. John, 10.ii.1940.

Misra (*loc. cit.*) showed that the sexes of *Barbus melanampyx* can be distinguished by their respective colouration. From the large series of fresh specimens examined by us from Travancore we are able to confirm Misra's account, but find that the colouration of the sexes varies to a certain extent. In some of the female specimens the dorsal fin is not stained with black while in some of the smaller examples the three lateral bands are only faintly marked. In a number of male specimens the entire body is dark so that the two broad lateral bands cannot be differentiated from each other. The tips of the caudal fin may be devoid of the usual black colour, and in certain examples the opercular spot is also indistinguishable. In fully mature specimens the tubercles on the snout extend in a broad patch all round the front border of the snout.

### **Barbus (Tor) mussullah** Sykes.

1841. *Barbus mussullah*, Sykes, *Trans. Zool. Soc. London* II, p. 356, pl. lxi, fig 4.

11 specimens, 60 to 260 mm. in length. Streams within a radius of 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, 12.iv.1940 and April 1941.
2 specimens, 42 and 53 mm. in length. Kallar stream at the foot of Ponmudi Hills, Western Ghats, South Travancore. S. Jones, April 1939.

Though Hora in his series of articles on the Game Fishes of India has not yet dealt with the Large-scaled Barbels of Peninsular India, the number of young and half-grown specimens under report seem to belong to *Barbus mussullah*. From a preliminary examination of the material from Peninsular India, Hora has found that this is the commonest species of these parts and that its range extends along the Satpura Trend to the Central Provinces.

### **Barbus (Puntius) pinnauratus** (Day).

1877. *Barbus pinnauratus*, Day, *Fish. India*, p. 561, pl. cxxxix, fig. 3.
1936. *Barbus pinnauratus*, John, *Journ. Bombay Nat. Hist. Soc.* XXXVIII, p. 711.
1937. *Barbus pinnauartus*, Hora, *Rec. Ind. Mus.* XXXIX, p. 336.
1938. *Barbus pinnauratus*, Hora, *Rec. Ind. Mus.* XL, p. 239.
1939. *Barbus pinnauratus*, Das, *Rec. Ind. Mus.* XLI, pp. 440, 441.

1 specimen, 85 mm. long. Kulathupuzha, a tributary of Kallada R., Central Travancore. (Collected from a pond-like accumulation of water surrounded by big boulders.) C. C. John, 14.ii.1940.
1 specimen, 111 mm. long. Chittar stream at Palode, South Travancore. C. C. John, 10.ii.1940.

In his recent publications, Hora has referred to the remarkable distribution of *Barbus pinnauratus* and indicated its close similarity to several species known from India and Burma. The specimens under report possess the characteristic colouration of the species and in other respects also represent the typical form.

### **Barbus (Puntius) ticto** Hamilton.

1939. *Barbus (Puntius) ticto*, Hora, Misra & Malik, *Rec. Ind. Mus.* XLI, pp. 263-279.

1 specimen, 32 mm. long. Achenkovil R., 7 miles south-east of Konni, Central Travancore. C. C. John, 17.ii.1940.

In the paper referred to above, Hora, Misra and Malik adduced evidence to show that Day's *Barbus punctatus* from Peninsular India, characterized by the possession of a complete lateral line, is synonymous with *B. ticto*. In the specimen under report, the lateral line is more or less complete. It is worthwhile to mention here once again that examples of *B. ticto* with complete lateral line have so far been found both in Burma and Siam and in Peninsular India.

### **Garra mullya** (Sykes).

1921. *Garra mullya*, Hora, *Rec. Ind. Mus.* XXII, pp. 658-660.

28 specimens, 63 to 186 mm. in length. Streams within a radius of about 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, 12.iv.1940 and April 1941.

10 specimens, 61 to 121 mm. in length. A tributary of Manimala R., Erumeli, Central Travancore. C. C. John, 20.ii.1940.

2 specimens, 77 and 87 mm. in length. Pool at the foot of the largest fall of Peruntenaruvi, a tributary of Pamba R., at Edakadathy, Central Travancore. C. C. John, 11.ii.1940.

1 specimen, 45 mm. long. Achenkovil R., 7 miles south-east of Konni, Central Travancore. C. C. John, 17.ii.1940.

12 specimens, 72 to 114 mm. in length. Near the source of Kallada R., 4 miles east of Thenmalai, Central Travancore. C. C. John, 9.ii.1940.

9 specimens, 71 to 105 mm. in length. Kulathupuzha, a tributary of Kallada R., Central Travancore. (Collected from a pond-like accumulation of water surrounded by big boulders.) C. C. John, 14.ii.1940.

2 specimens, 43 and 55 mm. in length. Kallar stream at the foot of Ponmudi Hills, Western Ghats, South Travancore. S. Jones, April 1939.

*Garra mullya* is the most widely distributed hill-stream fish of the Western Ghats and is represented by a large number of young, half-grown and adult specimens in the collection under report. It has been found to be equally abundant along the western portion of the Satpura Trend of mountains. The species can readily be distinguished by the absence of a proboscis on the snout, by the presence of tubercular areas, and by the fact that the tip of the snout is marked off by two short lateral grooves. In certain examples the tubercles are few and not well marked.

### **Bhavania australis** (Jerdon).

1941. *Bhavania australis*, Hora, *Rec. Ind. Mus.* XLIII, p. 225, pl. viii, figs. 1-3.

12 specimens, 40 to 111 mm. in length. Streams within a radius of about 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, 12.iv.1940 and April 1941.

1 specimen, 94·5 mm. long. Kallar stream at the foot of Ponmudi Hills, Western Ghats, South Travancore. S. Jones, April 1939.

Hora (*loc. cit.*) has given a detailed account of *Bhavania australis* and discussed its affinities with other genera of the Homalopterinae. The species seems to be fairly common in the southern portion of the Western Ghats.

### **Travancoria jonesi** Hora.

1941. *Travancoria jonesi,* Hora, *Rec. Ind. Mus.* XLIII, p. 230, pl. viii, figs. 5-9.

20 specimens, 22 to 100 mm. in length. Streams within a radius of about 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, 12.iv.1940 and April 1941.

An account of *Travancoria jonesi* was recently published by Hora (*loc. cit.*) in his paper on the Homalopterid fishes from Peninsular India. The genus *Travancoria* is very closely allied to *Bhavania,* but differs in having more extensive gill-openings and a larger number of rostral barbels. The species is known only from Travancore.

### **Lepidocephalus thermalis** (Cuv. & Val.).

1878. *Lepidocephalichthys thermalis,* Day, *Fish. India,* p. 610, pl. clv, fig. 3.

20 specimens, 29 to 33 mm. in length. Pampadampara Tank, Western Ghats, North Travancore. S. Jones, March 1940.
42 specimens, 33·5 to 70 mm. in length. Streams within a radius of about 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, 12.iv.1940 and April 1941.

*Lepidocephalus thermalis* is known from Peninsular India and Ceylon. In general facies, it is closely allied to *L. guntea* of northern India, but Day distinguished the two species by the size of the head and the number of transverse rows of scales on the body. It is likely that when large series of specimens from different localities are carefully examined, the two forms may prove to be local races of the same species.

### **Nemachilus evezardi** Day.

1878. *Nemachilus evezardi,* Day, *Fish India,* p. 613, pl. cliii, fig. 11.
1919. *Nemachilus evezardi,* Annandale, *Rec. Ind. Mus.* XVI, p. 126, pl. i, figs. 2, 2*a*.
1938. *Nemachilus evezardi,* Hora, *Rec. Ind. Mus.* XL, p. 241.

42 specimens, about 25 mm. in length. Streams within a radius of about 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, April 1941.
43 specimens, 13 to 56 mm. long. Dhobikana, a small stream close to Pampadampara, Western Ghats, North Travancore. S. Jones, March 1940.
8 specimens, 31 to 41 mm. in length. Sannyasa-ode, near Pampadampara, Western Ghats, North Travancore. S. Jones, April 1940.

*Nemachilus evezardi* was hitherto known from the Western Ghats, near Bombay, the Pachmarhi hills, Central Provinces, and the Bailadila range, Bastar State, Central Provinces. It is recorded here from the Travancore hills for the first time. The distribution of the species is of some interest as indicating the continuity of these hills at some earlier period.

*N. evezardi* is readily distinguished from other Indian species of the genus by the possession of well-marked nasal barbels. The colouration is very variable, but is quite characteristic of the species.

## **Nemachilus guentheri** Day.

(Plate IX, figs. 2-5.)

1867. *Nemacheilus guentheri*, Day, *Proc. Zool. Soc. London*, p. 285.
1868. *Nemachilus guentheri*, Günther, *Cat. Fish. Brit. Mus.* VII, p. 361.
1872. *Nemacheilus guentheri*, Day, *Journ. As. Soc. Bengal* XLI, p. 195.
1878. *Nemacheilus guentheri*, Day, *Fish. India*, p. 615, pl. clvi, fig. 10.
1889. *Nemachilus guentheri*, Day, *Faun. Brit. Ind.* Fish. I, p. 228.

2 specimens, 27 and 51·2 mm. in length. Streams within a radius of 5 miles round Pampadampara Western Ghats, North Travancore. S. Jones, April 1941.

Since the discovery of *Nemachilus guentheri* by Day about 74 years ago in the " Rivers along the lower slopes and base of the Neilgherry hills ", no other worker seems to have collected further material of this species. Günther's description is based on a typical specimen from Day's collection. Besides the two specimens collected by Mr. S. Jones as noted above, we have examined 3 specimens from the Dhoni forest in South Malabar collected by Mr. E. Burnes in May 1923, and 8 specimens collected by the late Dr. N. Annandale from the Nierolay stream, a tributary of the Bhavani river at the base of the Nilgiri Hills. These records show that the species is distributed probably all over the southern parts of the Western Ghats and the associated hill ranges.

In the specimens under report, the length of the head is contained from 5·10 to 5·69 times in the total length and from 4·16 to 4·49 times in the standard length. The head is broader than its height ; its width is contained from 1·56 to 1·86 times and its height from 1·80 to 2·04 times in its length. The eyes are situated almost in the middle of the head or slightly nearer to the tip of the snout than to the end of the opercular border ; the diameter of the eye is contained from 3·90 to 5·30 times in the length of the head, from 1·43 to 2·25 times in the length of the snout and from 0·83 to 1·40 times in the interorbital width. The head and the anterior part of the body are somewhat flattened while the tail is compressed from side to side. The depth of the body is contained from 8·68 to 9·79 times in the total length and from 6·85 to 7·72 times in the standard length. The caudal peduncle is almost as long as high or may be slightly longer.

From the material before us, it seems that the colouration is very variable. In a specimen from the Dhoni forest, the dorsal surface is uniformly dark with faint indications of the pale bands in the tail region. As pointed out by Day, there are usually three rows of pale spots (Pl. IX, fig. 2) but their extent varies practically with each individual. A black mark is invariably present in the axil of the pectoral fin and the caudal fin is provided with three W-shaped bands across it. There is a deep, short, vertical bar at the base of the caudal fin.

The specimens from the Nierolay stream (Pl. IX, fig. 4) and Pampadampara are much lighter in colour. The general colour of the body is pale olivaceous ; the dorsal surface of the head is grayish, while the entire ventral surface is much lighter. The body is marked with 3 rows of spots of different sizes and form ; they impart a very characteristic appearance to the species.

*Measurements in millimetres.*

| | Dhoni Forest, S. Malabar. | | | Pampadam-para. | Nierolay Stream, Nilgiris. | |
|---|---|---|---|---|---|---|
| Total length | 45·6 | 51·8 | 52·0 | 51·2 | 40·8 | 56·8 |
| Length of caudal | 9·1 | 10·6 | 10·4 | 10·8 | 7·2 | 12·0 |
| Length of head | 8·2 | 9·5 | 10·0 | 9·0 | 8·0 | 10·6 |
| Height of head | 4·1 | 4·9 | 4·9 | 5·0 | 4·0 | 5·5 |
| Width of head | 5·2 | 5·1 | 5·8 | 5·3 | 5·0 | 6·8 |
| Depth of body | 5·2 | 5·6 | 5·9 | 5·9 | 4·9 | 5·8 |
| Diameter of eye | 2·1 | 2·1 | 2·4 | 2·0 | 1·8 | 2·0 |
| Length of snout | 3·0 | 3·4 | 3·9 | 3·9 | 2·6 | 4·5 |
| Interorbital distance | 2·0 | 2·5 | 2·6 | 2·4 | 1·5 | 2·8 |
| Length of dorsal | 7·2 | 9·0 | 9·8 | 8·0 | 7·0 | 8·5 |
| Length of pectoral | 7·2 | 9·1 | 9·9 | 8·9 | 7·8 | 10·0 |
| Length of ventral | 6·7 | 8·1 | 9·0 | 7·7 | 6·0 | 8·9 |
| Length of anal | 6·1 | 7·2 | 8·1 | 7·0 | 5·2 | 7·7 |
| Length of caudal peduncle | 4·6 | 5·8 | 5·5 | 5·0 | 4·2 | 5·0 |
| Least height of caudal peduncle | 4·6 | 5·0 | 5·5 | 4·6 | 3·8 | 5·0 |

## **Nemachilus triangularis** Day.

1865. *Nemacheilus triangularis*, Day, *Proc. Zool. Soc. London*, p. 295.
1865. *Nemacheilus triangularis*, Day, *Fish. Malabar*, p. 203, pl. xiv, fig. 1.
1868. *Nemachilus triangularis*, Günther, *Cat. Fish. Brit. Mus.* VII, p. 352.
1872. *Nemacheilus triangularis*, Day, *Journ. As. Soc. Bengal* XLI, p. 194.
1878. *Nemacheilus triangularis*, Day, *Fish. India*, p. 619, pl. cliii, fig. 10.
1889. *Nemachilus triangularis*, Day, *Faun. Brit. Ind.* Fish. I, p. 234.
1909. *Nemachilus triangularis*, Jenkins, *Rec. Ind. Mus.* III, p. 289.
1929. *Nemachilus triangularis*, Pillay, *Journ. Bombay Nat. Hist. Soc.* XXXIII, p. 710.
1936. *Nemachilus triangularis*, John, *Journ. Bombay Nat. Hist. Soc.* XXXVIII, p. 710.

6 specimens, 45 to 73 mm. in length. Streams within a radius of about 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, 12.iv.1940, and April 1941.

4 specimens, 42 to 49 mm. in length. Manimala R., near Kangirappally, Central Travancore. C. C. John, 26.iii.1940.

6 specimens, 38 to 56 mm. in length. Achenkovil R., 7 miles south-east of Konni, Central Travancore. C. C. John, 17.ii.1940.

1 specimen, 52 mm. long. Kulathupuzha, a tributary of Kallada R., Central Travancore. C. C. John, 14.ii.1940.

8 specimens, 42 to 64 mm. in length. Kallar stream at the foot of Ponmudi Hills, Western Ghats, South Travancore. S. Jones, April 1939.

Day described *Nemachilus triangularis* from two specimens collected at Mundikyum, Travancore. The type-specimens are now preserved in the collection of the British Museum and, according to Day, the longer of the two is 2·1 inches in total length. There appears to be considerable inconsistency in Day's earlier and later accounts of the species regarding the proportions of the various parts of the body to the total length and, moreover, Day's illustration of the fish, as has already been pointed out by Günther, is not satisfactory. In view of this, we give below a complete description of the species and figures from fresh specimens.

D.2/8 ; A.2/5 ; P.11 ; V.8.

*Nemachilus triangularis* is a pretty loach with a very characteristic colouration ; it is almost subcylindrical with the head and anterior

part of body slightly depressed. The head is conical and bluntly pointed anteriorly; its length is contained from 4·09 to 5·32 times in the standard length and from 5·13 to 7·11 times in the total length. The height of the head is contained from 1·45 to 1·88 times and its width from 1·28 to 1·55 times in its length. The eyes are of moderate size, are situated almost in the middle of the length of the head, and are not visible from below; the diameter of the eye is contained from 3·60 to 5·00 times in the length of the head, from 1·33 to 2·14 times in the length of the snout and from 0·80 to 1·57 times in the interorbital width. In the males there is a small, obtuse projection of the preorbital below the anterior corner of the eye. The nostrils are situated considerably nearer to the anterior border of the eye than to the tip of the snout; they are separated by a prominent flap. There are six moderately long barbels. The lips are thick, fimbriated and continuous at the angles of the mouth; the lower lip is interrupted in the middle. The inter-maxillaries form a beak-shaped, median projection, which, when the mouth is closed, lies in front of the lower jaw.

The depth of the body is contained from 6·28 to 9·17 times in the total length and from 5·06 to 7·70 times in the standard length. The caudal peduncle is well formed and is generally somewhat higher than long. The body is covered with small distinct scales and the lateral line is fairly extensive and generally complete.

The dorsal fin originates slightly in advance of the pelvics and its commencement is almost equidistant from the tip of the snout and the base of the caudal fin. Its margin is straight and oblique, except at the anterior end where it is rounded. The pectoral is generally somewhat shorter than the head, but may be equal to it or even slightly longer; it is broadly pointed in the middle and is separated from the pelvics by a distance equal to a third of its length. The pelvics are distinctly pointed in the middle and bear a fleshy appendage in the axil; they do not extend as far as the anal opening. The caudal fin is deeply bifurcate.

The colour pattern varies considerably with age. In a young specimen, 35 mm. in total length, the ground colour is pale-olivaceous and there are about 7 dark bands descending from above to the sides; they are angularly directed backwards and some of the anterior ones are united by narrow longitudinal streaks. Most of the bands are edged with madder brown, and rounded yellow spots are present in the angular parts of some of the anterior bands. There are four bands on the head, one on the snout, one below the eye and two behind it in the opercular region. The dorsal fin is provided with two bands and there are indications of two bands on the caudal. The anal and the pelvic fins are also provided with one band each. There is a black blotch at the base of the caudal.

Day[1] described the colouration of a specimen, 52·5 mm. in total length, as: "Yellowish-banded, each band being edged with black; seven along the body, which pass backwards towards the lateral line, and consequently are disposed in a V-shaped manner; one band passes over the operculum, a second through the eye and a third from the

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[1] Day, F., *Proc. Zool. Soc. London*, p. 295 (1865).

orbit to the angle of the mouth. Dorsal with three irregular rows of black spots. Pectoral, ventral and anal unspotted, but darkest at their margins. Three black bands on the caudal, which has also a black base."

In a specimen, 72 mm. in total length, the colour pattern is still further modified. The ground colour of the head and the body is grayish and the pale bands on the body are broken up. There are seven bands, the anterior five are directed backwards, while the last two are vertical and are conspicuously edged with madder brown. There are a number of yellowish patches of different sizes and patterns above the lateral line. Five yellowish bands are present on the head and the colouration of the fins is similar to that described by Day.

*Distribution.*—Travancore. The specimens figured here were collected by the late Dr. N. Annandale at Courtallum, Travancore.

*Measurements in millimetres.*

| | Pampadam-para. | | Kallar Stream. | | | Achenkovil R. | | | Kula-thu-puzha. | Manimala R. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total length .. | 55·0 | 70·5 | 42·0 | 57·0 | 67·5 | 38·5 | 53·2 | 56·5 | 51·5 | 42·5 | 48·0 | 49·2 |
| Length of caudal .. | 8·8 | 12·0 | 9·0 | 11·0 | 15·0 | 7·8 | 11·5 | 11·0 | 11·2 | 8·5 | 9·5 | 10·5 |
| Length of head .. | 9·0 | 11·0 | 7·0 | 9·0 | 11·5 | 7·5 | 10·0 | 10·0 | 9·0 | 7·8 | 8·5 | 8·0 |
| Height of head .. | 5·5 | 7·0 | 4·0 | 5·5 | 7·0 | 4·0 | 5·5 | 6·0 | 5·5 | 4·5 | 5·0 | 5·5 |
| Width of head .. | 6·5 | 8·0 | 5·0 | 7·0 | 8·0 | 5·0 | 7·0 | 7·0 | 6·5 | 5·5 | 5·5 | 5·8 |
| Depth of body .. | 6·0 | 8·0 | 5·0 | 7·0 | 9·0 | 5·0 | 7·5 | 9·0 | 6·5 | 5·8 | 6·0 | 6·0 |
| Diameter of eye .. | 2·0 | 2·5 | 1·4 | 2·5 | 2·5 | 1·8 | 2·2 | 2·5 | 2·0 | 2·0 | 2·2 | 2·2 |
| Length of snout .. | 3·5 | 4·2 | 3·0 | 3·5 | 4·5 | 2·4 | 4·0 | 4·0 | 3·5 | 3·2 | 3·5 | 3·2 |
| Interorbital distance | 2·5 | 3·8 | 2·2 | 2·5 | 3·0 | 2·0 | 2·5 | 2·0 | 2·5 | 2·0 | 2·0 | 2·0 |
| Length of dorsal .. | 8·5 | 10·0 | 5·8 | 9·0 | 9·5 | 5·8 | 8·0 | 9·0 | 7·8 | 7·2 | 7·5 | 7·5 |
| Length of pectoral | 8·5 | 11·2 | 6·5 | 9·0 | 12·0 | 7·0 | 9·0 | 9·0 | 8·0 | 7·0 | 9·0 | 8·0 |
| Length of ventral | 7·8 | 9·2 | 6·0 | 8·5 | 10·0 | 5·8 | 7·0 | 8·5 | 7·5 | 5·5 | 7·5 | 6·2 |
| Length of anal .. | 7·0 | 9·2 | 5·0 | 7·0 | 8·5 | 5·0 | 7·0 | 7·0 | 6·0 | 5·8 | 7·0 | 6·2 |
| Length of caudal peduncle. | 5·0 | 8·0 | 4·0 | 5·8 | 5·8 | 3·5 | 5·0 | 5·5 | 4·0 | 4·0 | 4·0 | 4·5 |
| Least height of caudal peduncle. | 5·0 | 7·0 | 4·5 | 6·5 | 8·0 | 4·0 | 6·5 | 6·0 | 5·0 | 5·0 | 5·0 | 5·2 |

## **Callichrous bimaculatus** (Bloch).

1936. *Callichrous bimaculatus*, Hora, *Rec. Ind. Mus.* XXXVIII, pp. 356-361.

2 specimens, 144 and 149 mm. in length. Near the source of Kallada R., 4 miles east of Thenmalai, Central Travancore. C. C. John, 9.ii.1940.

1 specimen, 162 mm. long. Kulathupuzha, a tributary of Kallada R., Central Travancore. C. C. John, 14.ii.1940.

Recently one of us (Hora, *loc. cit.*) discussed the specific limits of *Callichrous bimaculatus*, and referred to the great range of variation exhibited by the species. In the specimens under report, the colouration varies considerably; one of the specimens is very dark all over, while the others are much lighter.

## **Batasio travancoria** Hora & Law.

1941. *Batasio travancoria*, Hora and Law, *Rec. Ind. Mus.* XLIII, pp. 40-42, pl. ii, figs. 7-9, text-fig. 3.

1 specimen, 95 mm. long. Pool at the foot of the largest fall of Perunтenaruvi, a tributary of Pamba R., at Edakadathy, Central Travancore. C. C. John, 11.ii.1940.

1 specimen, 85 mm. long. Near the source of Kallada R., 4 miles east of Thenmalai, Central Thravancorei. C. C. John, 9.ii.1940.

2 specimens, 78 and 105 mm. in length. Kulathupuzha, a tributary of Kallada R., Central Travancore. C. C. John, 14.ii.1940.

1 specimen, 75 mm. long. Chittar Stream at Palode, South Travancore. C. C. John, 10.ii.1940.

*Batasio travancoria* was recently described by us and remarks were made on the remarkable discontinuous distribution of the genus. It is known so far from the central and southern parts of Travancore.

## **Mystus cavasius** (Ham.).

1877. *Macrones cavasius,* Day, *Fish. India,* p. 447, pl. c, fig. 1.

1 specimen, 103 mm. long. Kulathupuzha, a tributary of Kallada R., Central Travancore. (Collected from a pond-like accumulation of water surrounded by big boulders.) C. C. John, 14.ii.1940.

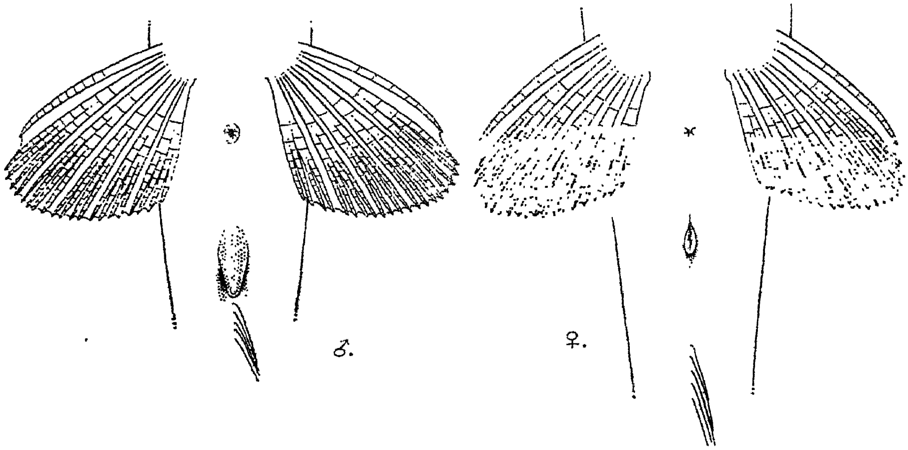
*Mystus cavasius* is widely distributed in the fresh waters of India and Burma. The specimen under report is a male with a well-developed urinogenital papilla; the free portion of the papilla being almost as long as the diameter of the eye. The testes are lobulated as in *M. malabaricus* (*vide infra,* p. 255).

## **Mystus malabaricus** (Jerdon).

1877. *Macrones malabaricus,* Day, *Fish. India,* p. 450, pl. ci, fig. 2.
1936. *Macrones malabaricus,* John, *Journ. Bombay Nat. Hist. Soc.* XXXVIII, p. 709.

2 specimens, 89 and 111 mm. in length. A tributary of Manimala R., Erumeli, Central Travancore. C. C. John, 20.ii.1940.
6 specimens, 95 to 119 mm. in length. Kulathupuzha, a tributary of Kallada R., Central Travancore. (Collected from a pond-like accumulation of water surrounded by big boulders.) C. C. John, 14.ii.1940.
1 specimen, 117 mm. long. Achenkovil R., 7 miles south-east of Konni, Central Travancore. C. C. John, 17.ii.1940.
3 specimens, 99 to 118 mm. in length. Near the source of Kallada R., 4 miles east of Thenmalai, Central Travancore. C. C. John, 9.ii.1940.
3 specimens, 91 to 113 mm. in length. Chittar stream at Palode, South Travancore. C. C. John, 10.ii.1940.

In Dr. C. C. John's collection there are 15 male specimens from 5 localities, as listed above, which we refer to *Mystus malabaricus* (Jerdon).




TEXT-FIG. 3.—External urinogenital structures in the male and female of *Mystus malabaricus* (Jerdon). Male: × 2; Female: × $2\frac{2}{3}$.

The males are provided with a urinogenital papilla, the size of which depends upon the sexual maturity of the individual irrespective of its

length. In immature specimens the testes are ribbon-like structures but become greatly enlarged and highly lobulated in adult males. The urinogenital duct opens at the extremity of the papilla. In the females the urinogenital opening is a slit-like aperture bordered by thickened lips. On account of these secondary sexual characters, the males and females can be distinguished readily. The anal opening is situated at a considerable distance in front of the urinogenital opening.

The presence of a urinogenital papilla is a fairly common occurrence among Siluroid fishes. Mukerji [1] recorded it in the case of *Glyptosternum reticulatum* McClelland. Day (*loc. cit.*, pp. 449, 450) referred to the presence of an anal papilla (=urinogenital papilla) in the case of two species of *Macrones* described and figured by him, *viz.*, *M. keletius* (Cuv. & Val.) and *M. armatus* Day. From among the specimens referred by Day to *M. malabaricus*, two are now preserved in the collection of Indian Museum ; one (No. 721) is a male with a well developed papilla and the second is a female (No. 504). The former is the original of his figure in the *Fishes of India* and it seems that the presence of the papilla was overlooked. *M. malabaricus* differs from *M. keletius* and *M. armatus* by its smooth head and other characters of minor importance.

Recently Mookerjee, Mazumdar and Das Gupta[2] described similar urinogenital structures in *Mystus gulio* (Ham.), but used for them anthropomorphic terms and by implication assumed for them copulatory functions without giving reasons for their views. We found similar organs in all the species of *Gagata* and *Batasio* studied by us[3].

*M. malabaricus* is known from the Malabar Coast, Wynaad Hills and the hill ranges of Travancore.

### **Glyptothorax madraspatanus** (Day).

1938. *Glyptothorax madraspatanus*, Hora, *Rec. Ind. Mus.* XL, p. 370.

1 specimen, 101 mm. long. Pampadampara, Western Ghats, North Travancore. S. Jones, 12.iv.1940.

2 specimens, 67 and 110 mm. in length. Streams within a radius of 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, April 1941.

1 specimen, 173 mm. long. Pool at the foot of the largest fall of Peruntenaruvi, a tributary of Pamba R., at Edakadathy, Central Travancore. C. C. John, 11.ii.1940.

In his key to the Indian species of the genus *Glyptothorax*, Hora [4] included *G. madraspatanus* in the group in which the ventral surface of the outer rays of the paired fins is not plaited. In the larger specimen under report, the skin on the ventral surface of the pectoral spine and that of the two outer rays of the pelvic fins form an adhesive pad of longitudinal grooves and ridges similar to those of the thoracic adhesive apparatus. It seems probable that this character, which is directly correlated with the rapidity of the current, is of little taxonomic value.

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[1] Mukerji, D. D., *Mem. Conn. Acad.* X, art. xviii, p. 329 (1936).

[2] Mookerjee, H. K., Mazumdar, S. R. and Das Gupta, B., *Ind. Journ. Vet. Sci. Animal Husb.* X, p. 295 (1940).

[3] Hora, S. L. and Law, N. C., *Rec. Ind. Mus.* XLIII, pp. 9-42 (1941).

[4] Hora, S. L., *Rec. Ind. Mus.* XXV, p. 12 (1923).

The lower lobe of the caudal fin of the larger specimen is abnormal; it is rounded instead of being pointed and has a Y-shaped whitish area in its distal portion.

**Xenentodon cancila** (Ham.).

1877. *Belone cancila,* Day, *Fish. India,* p. 511, pl. cxviii, fig. 5.

1 specimen, 222 mm. long. Pool at the foot of the largest fall of Peruntenaruvi, a tributary of Pamba R., at Edakadathy, Central Travancore. C. C. John, 11.ii.1940.

*Xenentodon cancila* is widely distributed in the fresh waters of India and on account of its characteristic beak can be readily distinguished from other kinds of fish.

**Ophicephalus gachua** Ham.

1876. *Ophiocephalus gachua,* Day, *Fish. India,* p. 367.

5 specimens, 82 to 123 mm. in length. Streams within a radius of about 5 miles round Pampadampara, Western Ghats, North Travancore. S. Jones, 12.iv.1940 and April 1941.
1 specimen, 18 mm. long. Manimala R., near Kangirappally, Central Travancore. C. C. John, 26.iii.1940.
6 specimens, 36 to 51 mm. in length. Achenkovil R., 7 miles south-east of Konni, Central Travancore. C. C. John, 17.ii.1940.
1 specimen, 47 mm. long. Kulathupuzha, a tributary of Kallada R., Central Travancore. (Collected from a pond-like accumulation of water surrounded by big boulders.) C. C. John, 14.ii.1940.

*Ophicephalus gachua* is represented in the collection by several young and half-grown specimens. This species is widely distributed throughout the Oriental Region.

**Mastacembelus armatus** (Lacép.).

1876. *Mastacembelus armatus,* Day, *Fish. India,* p. 340, pl. lxxiii, fig. 2.

1 specimen, 225 mm. long. Pool at the foot of the largest fall of Peruntenaruvi, a tributary of Pamba R., at Edakadathy, Central Travancore. C. C. John, 11.ii.1940.
2 specimens, 64 and 257 mm. in length. Achenkovil R., 7 miles south-east of Konni, Central Travancore. C. C. John, 17.ii.1940.

*Mastacembelus armatus* is a widely distributed Indian fish; its range extends as far as China. As has already been noted by Day and other workers, the colouration of the species varies considerably with growth, and very young specimens[1] of about 2 to 3 inches in length look quite different from the adult.

[1] Hora, S. L. and Mukerji, D. D., *Rec. Ind. Mus* XXXVIII, p. 145 (1936).

## EXPLANATION OF PLATE IX.

### THE FRESHWATER FISH OF TRAVANCORE.

*Barbus (Puntius) curmuca* (Hamilton).

FIG. 1.—Lateral view of a specimen showing the black-tipped caudal and tubercles on the side of the head: × $\frac{7}{8}$.

*Nemachilus guentheri* Day.

FIG. 2.—Lateral view of a female specimen from Dhoni forest, S. Malabar: × *ca.* $2\frac{1}{4}$.

FIG. 3.—Ventral surface of head and anterior part of body of same: × *ca.* $2\frac{1}{4}$.

FIG. 4.—Lateral view of a male specimen from Nierolay stream, Nilgiri Hills: × *ca.* 2.

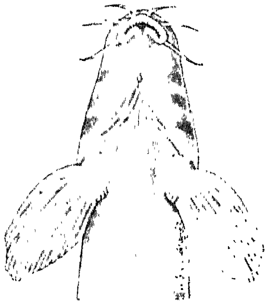
FIG. 5.—Ventral surface of head and anterior part of body of same: × *ca.* 2.

*Nemachilus triangularis* Day.

FIG. 6.—Lateral view of a juvenile specimen from Courtallum, Travancore: × *ca.* 3.

FIG. 7.—Ventral surface of head and anterior part of body of same: × *ca.* 3.

FIG. 8.—Lateral view of an adult specimen from Courtallum, Travancore, showing characteristic colouration of the species: × *ca.* $1\frac{2}{3}$.



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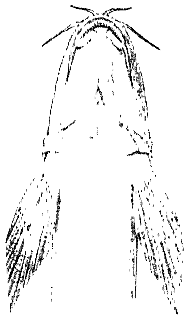

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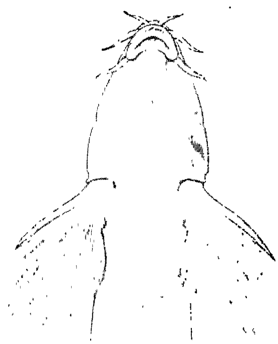

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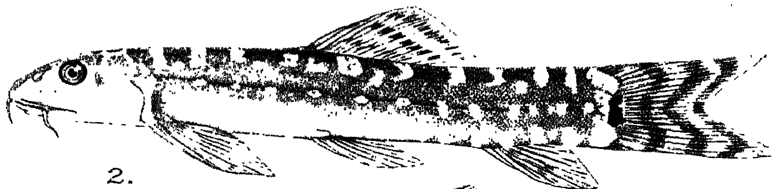

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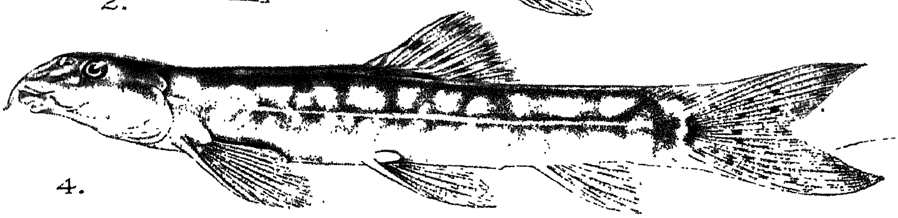

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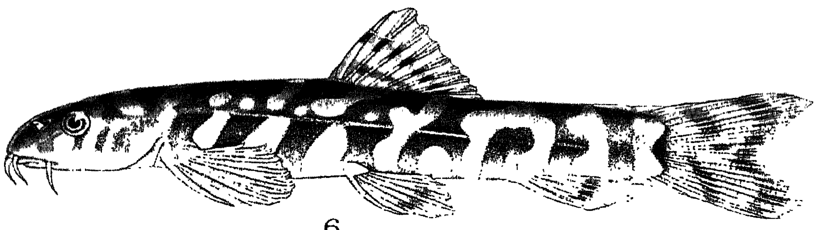

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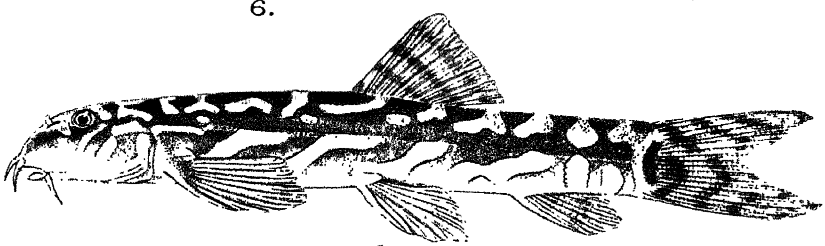

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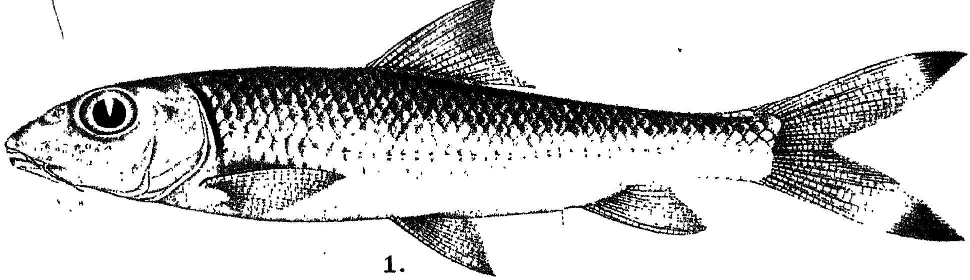

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Vol. XLIII, Part III, pp. 361—373

## Fishes of the Satpura Range, Hoshangabad District, Central Provinces.

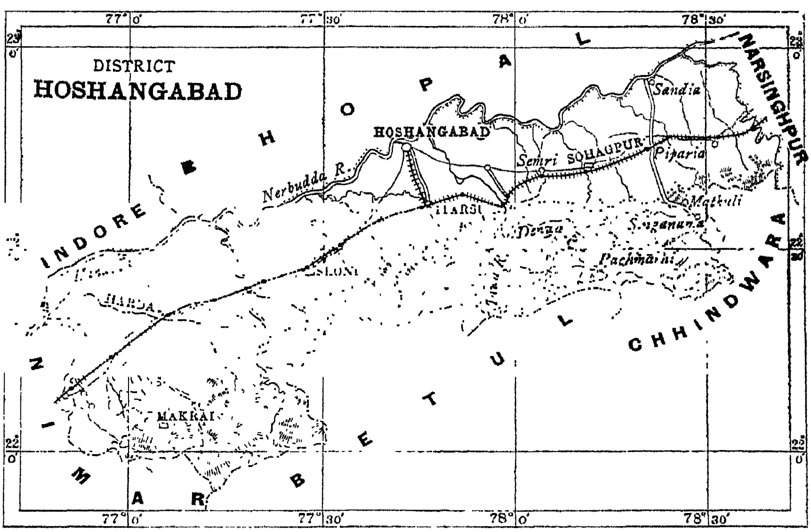
By
SUNDER LAL HORA
and
K. KRISHNAN NAIR

CALCUTTA:
SEPTEMBER, 1941

# FISHES OF THE SATPURA RANGE, HOSHANGABAD DISTRICT, CENTRAL PROVINCES.

*By* SUNDER LAL HORA, *D.Sc.*, *F.R.S.E.*, *F.N.I.*, *Assistant Superintendent and* K. KRISHNAN NAIR, *M.Sc.*, *Gallery Assistant, Zoological Survey of India, Calcutta.*

In 1937, one of us[1], while referring to the distribution of Himalayan fishes, explained the occurrence of similar forms in the Eastern Himalayas and the Assam Hills on the one hand and the south-western hills of Peninsular India on the other by suggesting that the Satpura Trend of mountains probably stretched across India as a continuous range from the Assam Himalayas to Gujarat from the Miocene period till comparatively recent times. To test this hypothesis, the Zoological Survey of India has made collections in the Rajmahal Hills[2], Santal Parganas[3], Hazaribagh Hills[4], headwaters of the Mahanadi River, Raipur District[5], and from the Satpura Range, Hoshangabad District.




Map of the Hoshangabad District, Central Provinces, showing the localities in which collections of fish were made.

The last locality was visited by Drs. B. N. Chopra and M. L. Roonwal, who made an extensive collection of fish in the small hill-streams arising from the Satpura Range in the vicinity of the Pachmarhi Plateau and

[1] Hora, S. L., *Rec. Ind. Mus.* XXXIX, p. 255 (1937).

[2] Hora, S. L., *Rec. Ind. Mus.* XL, pp. 169-181 (1938).

[3] Mr. K. N. Das is preparing a report on the fish collected by Dr. H. A. Hafiz in the Santal Parganas during November-December, 1938.

[4] Das, K. N., *Rec. Ind. Mus.* XLI, pp. 437-450 (1939).

[5] Hora, S. L., *Rec. Ind. Mus.* XLII, pp. 365-374 (1940).

from comparatively sluggish streams in the plains at Itarsi and Harda. Dr. Chopra has very kindly supplied us the following note on the physical features and the ecological conditions of the area surveyed :

"The Hoshangabad District[1] in the Central Provinces of India lies between latitude 21° 53′ and 22° 59′ N. and longitude 76° 47′ and 78° 44′ E. It is a long and narrow strip of country stretching along the left bank of the Nerbudda, between the Vindhyan mountains and the Satpura hills, and includes parts of the latter range within its borders. The Nerbudda forms the northern boundary of the District.

"The drainage of the Hoshangabad District need not be considered in detail but for the purpose of this note it may be stated that many streams, large and small, flow down from the Satpuras, generally in a north-westerly direction, into the Nerbudda. The Nerbudda itself is a large river flowing between somewhat steep banks along the northern boundary of the District. From the eastern slopes of the Pachmarhi hills in the south-east corner of the District the water is collected in a large number of streams and flows into the Denwa which, after a short northerly course, turns due west near Matkuli, about 14 miles below Pachmarhi, and joins the Tawa which is the most important tributary of the Nerbudda in this District. The western slopes of the Pachmarhi hills are drained by the Sonbhadra, which flows north to join the Denwa. Another important tributary of the Denwa is the Nag Dewali, which rises near Pachmarhi in the deep gorge known as Jambudwip and descends north-westwards through the hills to join the Denwa. This stream forms a series of charming cascades. The Nerbudda has several other important tributaries also, but the only one that need be mentioned here is the Ajnal which passes close to Harda and joins the Nerbudda in the north-west corner of the District. Near Itarsi, practically in the centre of the District, a small stream flows in a north-westerly direction and joins the Lathia, before it falls into the Nerbudda.

"The plateau of Pachmarhi lies at an elevation of about 3,500 feet, with the Mahadeo hills of the Satpura range forming a rugged background of great beauty and rising in places to almost 4,500 feet above the sea-level. The plateau is formed of almost level or slightly undulating stretches of grassy glades, interspersed with clumps of forest trees. The prevailing sandstone, which is of great depth and succumbs readily to denudation, has, under the action of water, formed a maze of gorges and ravines in which numerous streams flow. The plateau receives a rainfall of about 77 inches a year and nearly the whole of it falls between June and September. The climate is rather mild, the average minimum and maximum temperatures ranging between 47·5° and 95·1°F.

"The plains consist of a rich alluvium, the average rainfall is about 47 inches per annum and the average minimum and maximum temperatures at Hoshangabad vary between 71·3° and 107·6° F.

"The survey was carried out in February and March, which are practically the driest months in the year in the District. The streams in the hills, that is, around the Pachmarhi plateau, had only a restricted flow, while those in the plains had naturally considerable quantities of water in them. In a few of the former the current was merely in the form of a trickle and in none was the flow very rapid, except near cascades and falls. There were pools in the course of most of these streams and rich collections were obtained in these pools. The bottom for the most part consisted of stones and pebbles mixed with sand and clay, but in the pools and in some other parts also there was a lot of mud. This was especially the case in some parts of the small streams round Badkachar. In some cases the water flowed over large rocks and boulders, some of which had been worn flat by the current; this was the case in the vicinity of the Small Water Fall, some parts of the stream in the Jambudwip gorge and that in the neighbourhood of the Pansy Pool. There was only a small amount of vegetation in most of the streams, except in some near Badkachar and those near Singanama. In many cases the country through which the streams were flowing was thickly wooded; this was especially the case with the streams near Pansy Pool, that near Rohrighat and the Jambudwip. The streams round Badkachar, that near Darmar and one or two others flowed through country which was for the most part bare. The water in all these streams was clear. In the hill-streams the dominant fish at this time of the year was *Garra mullya*. This fish was collected in practically every stream, sometimes in considerable numbers, and was found even in pools with a muddy bottom and slow current. Two species of *Nemachilus*, locally known as *Patharchat* (stone licker) were also met with practically everywhere, living under stones and hiding in the vegetation near banks. Another fish collected in some streams in considerable numbers is *Danio aequipinnatus*. This prominently striped fish was found to be the dominant form in streams round Badka-

[1] The information regarding physical features, etc., has been taken partly from the Hoshangabad District Gazetteer by Corbett and Russel (1908), and that about the distribution of fishes from the lists prepared by Dr. Hora and Mr. Nair.

char. at Rohrighat and in some streams round Singanama ; in these streams *Garra* was collected in comparatively smaller numbers. Several other species also were collected in these streams, the genera represented being *Parapsilorhynchus*, *Barbus*, *Barilius*, *Rasbora*, *Lepidocephalus*, and *Ophicephalus*.

" The streams in the plains differed considerably in their physical conditions from those described above. In most of these there was a considerable flow of water, the current was sluggish to moderately swift and the bottom for the most part consisted of sand and mud, with occasional patches of small stones and pebbles. There was considerably more vegetation in the water than in the hill-streams and in the Ajnal nullah near Harda there was such a luxurious growth of algae and other vegetation in the stream that it required considerable efforts to wade through it. This thick vegetation afforded excellent protection to large numbers of fish and though plenty of them could be seen darting about from cover to cover, it was difficult to bag them. The course of these streams lay through country that was for the most part only sparsely wooded, and in parts was quite bare. The water was more or less clear. *Garra* was practically absent in these streams and was collected in small numbers only in the stream near Mehragaon, close to Itarsi. *Nemachilus* was collected in practically all these streams, but of the two species found in the hills, one, *N. evezardi*, was totally absent in the plains, while the other, *N. dayi*, was common throughout. A third species of *Nemachilus*, *N. botius*, which was met with rather rarely in the hills, was found in fair numbers in these streams. There are several species that were common to both the localities, but some of these were more abundant in one than in the other. Barbels were far more common, both in the number of species and in individuals, in the plains than in streams round Pachmarhi. Among the genera met with in the streams in the plains only may be mentioned *Brachydanio*, *Esomus*, *Labeo*, *Rohtee*, *Oreichthys*, *Amblyceps*, *Xenentodon*, *Badis*, *Laguvia*, *Glossogobius*. In all 26 genera were collected ; of these, nine were found in the hill streams also."

## DESCRIPTIONS OF LOCALITIES WITH LISTS OF FISHES COLLECTED FROM EACH.

### *Jambudwip stream, about 2 miles north-west of Pachmarhi.* 9. ii. 1941.

This is a typical hill-stream running in a deep well-wooded valley. The bottom is rocky or strewn over with stone and pebbles in some places and muddy in others. The current is not very fast, except in the regions of small falls and cascades. Portions of the stream contain plenty of vegetation. Here and there large pools are formed with the bottom generally muddy. In some places the stream flows as a small trickle over a bed of large flat rocks.

| | Length in mm. | No. of specimens |
|---|---|---|
| *Garra mullya* (Sykes) .. .. . | 59—69 | 4 |
| *Parapsilorhynchus tentaculatus* (Ann.) .. . | 26—41 | 5 |
| *Nemachilus dayi* Hora .. .. . | 26—40 | 12 |
| *Nemachilus evezardi* Day .. .. . | 18—52 | 11 |

### " *Pansy Pool* ", *about 4 miles south-west of Pachmarhi.* 10. ii. 1941.

The Denwa river runs in places through a deep *khud* between high rocks and forms a series of deep pools, popularly known as " Pansy Pool ". The current is generally sluggish but in between the pools rapids are formed. The bottom consists of rocks and stones intermixed with pebbles and sand. Parts of the stream are thickly shaded, but there is little vegetation in the water.

| | Length in mm. | No. of specimens. |
|---|---|---|
| *Barbus (Tor) khudree* Sykes.. .. .. | 33 | 1 |
| *Garra mullya* (Sykes) .. .. .. | 39—76 | 20 |
| *Nemachilus dayi* Hora .. .. .. | 21—57 | 8 |
| *Nemachilus evezardi* Day .. .. .. | 23—28 | 3 |

*"Small Waterfall" about 2 miles east of Pachmarhi.* 11. ii. 1941.

The waterfall is about 75 feet high and below it there is a typical hill-stream formed of rapids and pools in succession. The bottom is formed of pebbles and brownish sand, and the banks are overgrown with grasses and forest trees. Some of the pools are over 10 feet deep and the current in them is sluggish.

| | Length in mm. | No. of specimens |
|---|---|---|
| *Barilius bendelisis* Ham. .. | 46—85 | 13 |
| *Danio aequipinnatus* (McClell.) | 55—73 | 7 |
| *Barbus (Puntius) dorsalis* (Jerdon) | 53 & 56 | 2 |
| *Barbus (Puntius) ticto* Ham. . | 28—53 | 5 |
| *Parapsilorhynchus tentaculatus* (Ann.) | 31 | 1 |
| *Nemachilus evezardi* Day .. | 26—35 | 4 |

*Darmar stream near Darmar village, below Pachmarhi-Piparia Road about 3 miles north-east of Pachmarhi.* 12. ii. 1941.

A small stream with a comparatively slow current of clear water flowing over stones and boulders, and in places over sand and shingle, etc. In the course of the stream there are several pools with muddy bottom and a sluggish current. There is no vegetation in the water but there are some tall trees along the banks.

| | Length in mm. | No. of specimens |
|---|---|---|
| *Garra mullya* (Sykes) | 29—78 | 113 |
| *Nemachilus dayi* Hora | 25—83 | 16 |
| *Nemachilus evezardi* Day | 20—38 | 7 |

*Streams around Badkachar, about 6 miles north-west of Pachmarhi.* 14. ii. 1941.

The streams are small and sluggish with restricted flow over a bottom of stones and rocks. In places the bottom is muddy. There is very little of aquatic vegetation, but there are trees along the banks of the streams.

| | Length in mm. | No. of specimen |
|---|---|---|
| *Danio aequipinnatus* (McClell.) .. .. | 45—76 | 16 |
| *Parapsilorhynchus tentaculatus* (Ann.) .. .. | 23—28 | 7 |
| *Nemachilus dayi* Hora .. .. .. | 31—65 | 6 |

*Rohrighat stream near Rohrighat village, about 8 miles south-west of Pachmarhi.* 15. ii. 1941.

A small, comparatively sluggish stream running on two sides of the village. In places the stream runs through open country without any shade, while in other places the banks are very thickly wooded. There is very little aquatic vegetation. The bottom is mostly muddy, but

in places there are lots of stones. The stream forms several pools in its course.

| | Length in mm. | No. of specimens. |
|---|---|---|
| *Barilius bendelisis* Ham. .. | 105 & 110 | 2 |
| *Danio aequipinnatus* (McClell.) | 42—86 | 64 |
| *Rasbora daniconius* (Ham.) | 97 | 1 |
| *Garra mullya* (Sykes) .. | 43—75 | 7 |
| *Nemachilus dayi* Hora .. | 23—79 | 12 |
| *Ophicephalus gachua* Ham. | 120 | 1 |

*Choka mullah near Singanama on the Pachmarhi-Piparia Road, about 14 miles from Pachmarhi. 18 & 20. ii. 1941.*

A small sluggish stream with a muddy bottom, which is strewn over with rocks in places. Pools in the course of the stream are almost stagnant and have a lot of algae and other aquatic vegetation. The bottom consists of black mud, mixed with sand. The water is generally clear. This stream joins the Denwa a little below Singanama village.

| | Length in mm. | No. of specimens. |
|---|---|---|
| *Barilius bendelisis* Ham. .. | .. | Several young specimens. |
| *Danio aequipinnatus* (McClell.) | 49—72 | 11 |
| *Rasbora daniconius* (Ham.) .. | 41—78 | 7 |
| *Barbus (Puntius) dorsalis* (Jerdon) | 44 | 1 |
| *Barbus (Puntius) ticto* Ham. | 32—63 | 5 |
| *Barbus (Tor) khudree* Sykes. | 33 & 37 | 2 |
| *Garra mullya* (Sykes) .. | 57—65 | 5 |
| *Lepidocephalus guntea* (Ham.) | 60 & 66 | 2 |
| *Nemachilus dayi* Hora .. | 66 | 1 |
| *Ophicephalus gachua* Ham. .. | 83 & 88 | 2 |

*Denwa river near Singanama, on Pachmarhi-Piparia Road, about 14 miles from Pachmarhi.* 19 & 20. ii. 1941.

The Denwa opens out into a broad stream of clear water flowing over a bed of sand. with large rocks here and there. The water is clear and there is very little aquatic vegetation. The current is moderately swift. On the sides of the river there are isolated pools.

| | Length in mm. | No. of specimens |
|---|---|---|
| *Barilius bendelisis* Ham. .. | 27—98 | 58 |
| *Danio aequipinnatus* (McClell.) | 46—70 | 5 |
| *Rasbora daniconius* (Ham.) | 68 & 75 | 2 |
| *Barbus (Puntius) pinnauratus* (Day) | 82 | 1 |
| *Barbus (Puntius) ticto* Ham. | 25—47 | 3 |
| *Barbus (Tor) khudree* Sykes | 20—68 | 27 |
| *Garra mullya* (Sykes) .. | 56—80 | 9 |
| *Garra gotyla* (Gray) .. | 63 | 1 |
| *Nemachilus botius* (Ham.) .. | 76 | 1 |

*Mahabir nullah just behind the Rest House at Singanama on Pachmarhi-Piparia Road, 14 miles from Pachmarhi.* 20. ii. 1941.

The nullah consists of small, isolated pools with a small trickle of water flowing in between them. The bottom consists of rocks and stones with patches of sand and darkish mud. The water is clear. There is no aquatic vegetation.

| | Length in mm. | No. of specimens. |
|---|---|---|
| *Barilius bendelisis* Ham. | .. | Several young specimens. |
| *Danio aequipinnatus* (McClell.) | 42—75 | 30 |
| *Rasbora daniconius* (Ham.) | 49—91 | 17 |
| *Barbus pinnauratus* (Day) | 91 | 1 |
| *Barbus (Puntius) dorsalis* (Jerdon) | 50 & 64 | 2 |
| *Barbus (Puntius) ticto* Ham. | 40—66 | 5 |
| *Garra mullya* (Sykes) | 50 & 61 | 2 |
| *Lepidocephalus guntea* (Ham.) | 65 | 1 |
| *Nemachilus dayi* Hora | 38 & 45 | 2 |

*Machhuasa or Machha stream about* $1\frac{1}{2}$ *miles north of Piparia, and under Railway bridge close to Railway Station.* 22 & 23. ii. 1941.

A small stream of clear water flowing slowly over a bed of sand and clay. The vegetation consists of algae and grasses.

| | Length in mm. | No. of specimens |
|---|---|---|
| *Barilius bendelisis* Ham. | 45—71 | 14 |
| *Brachydanio rerio* (Ham.) | 22—30 | 43 |
| *Rasbora daniconius* (Ham.) | 69 | 1 |
| *Barbus (Puntius) ticto* Ham. | 25 & 27 | 2 |
| *Lepidocephalus guntea* (Ham. | 45—71 | 19 |
| *Nemachilus dayi* Hora | 26—32 | 6 |

*Stream near Mehra village, about* $1\frac{1}{2}$ *miles from Itarsi.* 24-26. ii. 1941.

It is a small sluggish stream running over a bed of gravel and mud. The banks are muddy and steep in places. The water is somewhat turbid and harbours large quantities of filamentous algae.

| | Length in mm. | No. of specimens |
|---|---|---|
| *Chela clupeoides* (Bloch) | 63 & 71 | 2 |
| *Laubuca laubuca* (Ham. | 56 | 1 |
| *Brachydanio rerio* (Ham.) | 25—28 | 11 |
| *Danio aequipinnatus* (McClell.) | 47 | 1 |
| *Esomus danricus* (Ham.) | 37—44 | 25 |
| *Rasbora daniconius* (Ham.) | 41—67 | 11 |
| *Barbus (Puntius) chrysopoma* (Jerdon) | 117 & 126 | 2 |
| *Barbus (Puntius) dorsalis* (Jerdon) | 41 | 1 |
| *Barbus (Puntius) sophore* Ham. | 35—48 | 4 |
| *Barbus (Puntius) ticto* Ham. | 32—58 | 49 |
| *Barbus (Puntius) titius* Ham. | 59—81 | 9 |
| *Barbus (Tor) khudree* Sykes | 104 | 1 |
| *Garra mullya* (Sykes) | 63—91 | 5 |
| *Labeo boggut* (Sykes) | 86—97 | 3 |
| *Rohtee cotio* (Ham.) | 50—58 | 7 |
| *Lepidocephalus guntea* (Ham.) | 52—67 | 10 |
| *Nemachilus dayi* Hora | 37—54 | 4 |
| *Mystus vittatus* (Bloch) | 65—88 | 17 |
| *Ophicephalus gachua* Ham. | 67—130 | 1 |
| *Ophicephalus punctatus* Bloch | 80—145 | 9 |
| *Glossogobius giuris* (Ham.) | 28—65 | 24 |

*Nerbudda river near Handia, about 13 miles north of Harda.* 27. ii. 1941.

A large river of clear water, flowing over a bed of sand and clay. There is a large number of rocks and boulders on the bank with pools in between them. Near the edge, there is a growth of grasses and algae. The bottom of the pools is muddy.

| | Length in mm. | No. of specimens |
|---|---|---|
| *Barbus* (*Puntius*) *ticto* Ham. . | 13—22 | 12 |
| *Barbus* (*Tor*) *khudree* Sykes . . | 35—43 | 3 |
| *Nemachilus dayi* Hora . . | 26—39 | 4 |

*Timarni nullah on the Timarni Road, a little south of Harda.* 28. ii. *and* 2. iii. 1941.

The nullah forms a branch of the Ajnal river, and is a fairly large stream of clear water, flowing over a bed of clay mixed with sand and gravel. In some places the bottom is stony. The vegetation consisting of grasses and algae is quite abundant in the shallower parts of the stream. The banks are fairly steep.

| | Length in mm. | No. of specimens |
|---|---|---|
| *Barilius bendelisis* Ham. . . . . | 32—111 | 14 |
| *Brachydanio rerio* (Ham.) . . . . | 26—31 | 3 |
| *Danio aequipinnatus* (McClell.) . . | 58 | 1 |
| *Barbus* (*Puntius*) *chrysopoma* (Jerdon) . . | 180 | 1 |
| *Barbus* (*Puntius*) *conchonius* (Ham.) . . | 38—64 | 10 |
| *Barbus* (*Puntius*) *dorsalis* (Jerdon) . . | 76 | 1 |
| *Barbus* (*Puntius*) *gugamio* (Ham.) . . | 33—41 | 11 |
| *Barbus* (*Puntius*) *pinnauratus* (Day) . . | 71—89 | 9 |
| *Barbus* (*Puntius*) *ticto* Ham. . . | 28—65 | 8 |
| *Barbus* (*Puntius*) *titius* Ham. . . | 84 | 1 |
| *Barbus* (*Tor*) *khudree* Sykes . . | 89—97 | 4 |
| *Garra mullya* (Sykes) . . . . | 45—90 | 7 |
| *Labeo boggut* (Sykes) . . . . | 57—95 | 12 |
| *Oreichthys cosuatus* (Ham.) . . | 28—44 | 5 |
| *Rohtee cotio* (Ham.) . . . . | 57—71 | 5 |
| *Lepidocephalus guntea* (Ham.) . . | 37 | 1 |
| *Nemachilus dayi* Hora . . . . | 25—60 | 26 |
| *Nemachilus botius* (Ham.) . . . . | 47 | 1 |
| *Mystus vittatus* (Bloch) . . . . | 85—90 | 3 |
| *Amblyceps mangois* (Ham.) . . . . | 23—44 | 6 |
| *Xenentodon cancila* (Ham.) . . . . | 76 & 108 | 2 |
| *Mastacembelus armatus* (Lacép.) . . | 95—148 | 4 |
| *Mastacembelus pancalus* (Ham.) . . | 79—85 | 3 |
| *Ophicephalus gachua* Ham. . . . . | 132 | 1 |
| *Badis badis* (Ham.) . . . . | 34 | 1 |
| *Glossogobius giuris* (Ham.) . . . . | 38—107 | 3 |

*Ajnal nullah near the Railway bridge about 2 miles south-west of Harda.* 1. iii. 1941.

A fairly large stream of clear water, running between steep banks over a bottom consisting mostly of small pebbles, etc., mixed with

sand and mud. The current is fairly swift. Large masses of algae were found growing in the water.

| | Length in mm. | No. of specimens. |
|---|---|---|
| *Notopterus notopterus* (Pallas) | 200 | 1 |
| *Barilius bendelisis* Ham. .. | .. | Several young specimens. |
| *Danio aequipinnatus* (McClell.) | 83 | 1 |
| *Barbus (Puntius) dorsalis* (Jerdon) | 71 | 1 |
| *Barbus (Puntius) pinnauratus* (Day) | 86 | 1 |
| *Barbus (Puntius) ticto* Ham. | 26—55 | 44 |
| *Barbus (Tor) khudree* Sykes | 71—142 | 8 |
| *Garra mullya* (Sykes) .. | 70—88 | 7 |
| *Labeo boggut* (Sykes) .. | 105 | 1 |
| *Lepidocephalus guntea* (Ham.) | 44—57 | 3 |
| *Nemachilus dayi* Hora .. | 27—60 | 14 |
| *Nemachilus botius* (Ham.) .. | 56—71 | 4 |
| *Xenentodon cancila* (Ham.) .. | 51 | 1 |
| *Mastacembelus armatus* (Lacép.) | 70—109 | 4 |
| *Ophicephalus punctatus* Day | 190 | 1 |
| *Glossogobius giuris* (Ham.) .. | 98 | 1 |

*Midkul nullah near the Railway bridge, about 2 miles south-west of Harda.* 3. iii. 1941.

The stream is about 40-60 feet wide and 2-5 feet deep. The current is sluggish and the vegetation consists of reeds, etc. The bottom consists of coarse sand and large stones here and there.

| | | Length in mm. | No. of specimens. |
|---|---|---|---|
| *Rasbora daniconius* (Ham. ).. | .. | 40 | 1 |
| *Barbus (Puntius) gugunio* (Ham.) | .. | 34—48 | 7 |
| *Barbus (Puntius) pinnauratus* (Day) | .. | 80 | 1 |
| *Barbus (Puntius) ticto* Ham. | .. | 22—51 | 7 |
| *Barbus (Tor) khudree* Sykes | .. | 85 | 1 |
| *Oreichthys cosuatus* (Ham.) .. | .. | 30—45 | 11 |
| *Nemachilus botius* (Ham.) .. | .. | 53—66 | 6 |
| *Mystus vittatus* (Bloch) .. | .. | 84 | 1 |
| *Laguvia rebeiroi* Hora .. | .. | 24 & 28 | 2 |
| *Mastacembelus armatus* (Lacép.) | .. | 88 | 1 |
| *Nandus nandus* (Ham.) .. | .. | 108 | 1 |
| *Badis badis* (Ham.) .. | .. | 18—46 | 6 |
| *Glossogobius giuris* (Ham.) .. | .. | 37 | 1 |

*Fishes purchased from markets at Sandia and Harda.*

Purchased in the market at Sandia, on River Nerbudda, 12 miles from Piparia on 21. ii. 1941.

| | Length in mm. | No. of specimens |
|---|---|---|
| *Mystus cavasius* (Ham.) .. .. .. | 108 | 1 |
| *Mystus vittatus* (Bloch) .. .. .. | 75—80 | 3 |

Purchased in the market at Harda on 28. ii. 1941.

| | Length in mm. | No. of specimens |
|---|---|---|
| *Rita pavimentata* Val. .. .. .. | 152—160 | 3 |
| *Mastacembelus armatus* (Lacép.) .. .. | 277 | 1 |

## SYSTEMATIC ACCOUNT.

The collection under report comprises 1,167 specimens belonging to 40 species. The systematic position of the species is shown in the following table:

Family NOTOPTERIDAE.

1. *Notopterus notopterus* (Pallas).

Family CYPRINIDAE.

Subfamily *ABRAMIDINAE.*

2. *Chela clupeoides* (Ham.).
3. *Laubuca laubuca* (Ham.).

Subfamily *RASBORINAE.*

4. *Barilius bendelisis* Ham.
5. *Brachydanio rerio* (Ham.).
6. *Danio aequipinnatus* (McClell.).
7. *Esomus danricus* (Ham.).
8. *Rasbora daniconius* (Ham.).

Subfamily *CYPRININAE.*

9. *Barbus* (*Puntius*) *chrysopoma* Cuv. & Val.
10. *Barbus* (*Puntius*) *conchonius* Ham.
11. *Barbus* (*Puntius*) *dorsalis* (Jerdon).
12. *Barbus* (*Puntius*) *guganio* (Ham.).
13. *Barbus* (*Puntius*) *pinnauratus* (Day).
14. *Barbus* (*Puntius*) *sophore* Ham.
15. *Barbus* (*Puntius*) *ticto* Ham.
16. *Barbus* (*Puntius*) *titius* Ham.
17. *Barbus* (*Tor*) *khudree* Sykes.
18. *Garra mullya* (Sykes).
19. *Garra gotyla* (Gray).
20. *Parapsilorhynchus tentaculatus* (Ann.).
21. *Labeo boggut* (Sykes).
22. *Oreichthys cosuatus* (Ham.).
23. *Rohtee cotio* (Ham.).

Family COBITIDAE.

24. *Lepidocephalus guntea* (Ham.).
25. *Nemachilus botius* (Ham.).
26. *Nemachilus dayi* Hora.
27. *Nemachilus evezardi* Day.

Family BAGRIDAE.

28. *Mystus cavasius* (Ham.).
29. *Mystus vittatus* (Bloch).
30. *Rita pavimentata* Val.

Family AMBLYCEPIDAE.

31. *Amblyceps mangois* (Ham.).

Family SISORIDAE.

32. *Laguvia ribeiroi* Hora.

Family BELONIDAE.

33. *Xenentodon cancila* (Ham.).

Family MASTACEMBELIDAE.

34. *Mastacembelus armatus* (Lacép.).
35. *Mastacembelus pancalus* (Ham.).

Family OPHICEPHALIDAE.

36. *Ophicephalus gachua* Ham.
37. *Ophicephalus punctatus* Bloch.

Family NANDIDAE.

38. *Nandus nandus* (Ham.).

Family PRISTOLEPIDAE.

39. *Badis badis* (Ham.).

Family GOBIIDAE.

40. *Glossogobius giuris* (Ham.).

Of the 40 species listed above, 26 belong to the order Cyprinoidea (22 Cyprinidae and 4 Cobitidae), 5 to the order Siluroidea (3 Bagridae, 1 Amblycepidae and 1 Sisoridae), while the remaining species are distributed among the families Notopteridae (1), Belonidae (1), Mastacembelidae (2), Ophicephalidae (2), Nandidae (1), Pristolepidae (1) and Gobiidae (1). With the exception of a few species of carp-minnows, all others are fairly well known and do not call for any comments from a systematic point of view. However, a few remarks are necessary on *Danio aequipinnatus* (McClelland), *Barbus* (*Puntius*) *chrysopoma* Cuv. & Val., *Nemachilus dayi* Hora, *Amblyceps mangois* (Ham.) and *Laguvia ribeiroi* Hora.

From a zoogeographical point of view the occurrence of *Amblyceps* and *Laguvia* in the Hoshangabad District shows the affinities of the fish-fauna of this region with that of the Assam Hills and the Eastern Himalayas. The former genus has been obtained from all the portions of the Satpura Trend surveyed by the Zoological Survey of India, while *Laguvia* was collected only in the Rajmahal Hills. The presence in

the collection of forms, such as *Barbus* (*Puntius*) *dorsalis* (Jerdon). *Garra mullya* (Sykes), *Parapsilorhynchus tentaculatus* (Ann.), *Labeo boggut* (Sykes), *Nemachilus dayi* Hora, *N. evezardi* Day and *Rita pavimentata* Val., shows that the fish-fauna of this part of the Satpuras is closely allied to the fauna of the Western Ghats. Some of these species, such as *Parapsilorhynchus tentaculatus*, *Nemachilus evezardi* and *Rita pavimentata*, were not found in the Sihawa range, Raipur District.[1] The remaining species are widely distributed in India and are, therefore, of little significance in a zoogeographical discussion. These studies have clearly shown that the Satpura Trend of mountains must have, at not a very remote period, acted as a highway for the dispersal of the Eastern Himalayan and Assam forms to the Western Ghats and that the Garo-Rajmahal Gap is only a comparatively recent feature in the physiography of India. Further, it is also clear that there must have been a continuity of waterways between the Western Ghats and the Satpuras of the Hoshangabad District not very long ago as can be inferred from a large number of identical species of limited range that are found in both the regions.

Though in his studies on 'The Distribution of Vertebrate Animals in India, Ceylon and Burma', Blanford[2] attached little importance to the distribution of freshwater fishes, it is significant that he had also come to similar conclusions as stated above from the distribution of other types of vertebrates. In describing the peculiarities of the fauna of the Indian Peninsula, he stated :

"The majority of the genera named are typically forest forms ; the species of the Bihar-Orissa area are, with very few exceptions, the same as those of Malabar, and may have inhabited the whole of Southern India before the forests of the Deccan and Carnatic were cleared. One circumstance seems strongly to support this view. There are two kinds of *Anthracoceros* in India, one of which inhabits Ceylon and the Western or Malabar coast as far north as Ratnagiri, whilst the other inhabits the lower Himalayas and countries to the eastward. Neither is known to be found in the Deccan or Carnatic. The two meet in the Bihar-Orissa area, the Malabar form to the south, the Himalayan to the north. It is scarcely probable that the southern species would exist in the area unless it once ranged over the country intervening between Chutia Nagpur and Malabar. In the same manner the southern grackle (*Eulabes religiosa*) meets the Himalayan and Burmese grackle (*E. intermedia*) in the same area, but is not known to be met with in the Deccan or Carnatic tracts.

"That the differences between the Bihar-Orissa province and the adjoining provinces of the Indian Peninsula are not ancient is, I think, shown by the absence of distinctive genera amongst the reptiles and batrachia."

With regard to the value of freshwater fishes in zoogeographical studies, Blanford (*loc. cit.*, p. 343) stated :

"The evidence afforded by freshwater fishes varies so much with the presence or absence of suitable habitats, such as lakes and rivers, that it is generally, I think, only applicable to large areas."

The distribution of hill-stream fishes, such as *Amblyceps*, *Laguvia*, *Garra*, *Parapsilorhynchus*, *Nemachilus*, etc., can only take place along hill ranges, so there is hardly any necessity to contemplate vast level tracts of the country to be once covered with forests in order to explain the distribution of any genus occurring in the Peninsula of India on the one hand and the hills of Assam and the Eastern Himalayas on the other. Such a continuity of hill-ranges was provided by the once

[1] Hora, S. L., *Rec. Ind. Mus.* XLII, pp. 365-374 (1940).

[2] Blanford, W. T.: *Phil. Trans. Roy. Soc. London* (B) CXCIV, p. 392 (1901).

extensive Satpura Trend[1] which stretched from the Assam Himalayas in the east to the Western Ghats in the west. We believe that the Satpura Trend not only provided a highway for the dispersal of the so-called Malayan fishes to Peninsular India, but also served as a route for the forest-loving forms among other groups of vertebrates that show a similar discontinuous range of distribution.

## **Danio aequipinnatus** (McClelland).

1878. *Danio aequipinnatus*, Day, *Fish. India*, p. 596, pl. cl., fig. 6.

In 1934, Hora and Mukerji[2] gave an artificial key to the species of *Danio* and distinguished three closely allied species by the following characters :

| | |
|---|---|
| I. A well-defined black mark near upper angle of gill-opening. | |
| A. Lateral bands breaking up anteriorly to form a mottled pattern. L. l. 37 ; L. tr. 10 (7½/2½) .. | *D. strigillifer* Myers. |
| B. Lateral bands not breaking up anteriorly to form a mottled pattern. Several well marked and uniform lateral bands. L. l. 34-36, L. tr. 10 or 11 (7½/2½ or 8½/2½) .. .. .. .. .. | *D. aequipinnatus*[3] (McClelland). |
| II. Black mark near upper angle of gill-opening absent. L. l. 32-34 ; L. tr. 11 (8½/2½) .. .. .. .. | *D. malabaricus* (Jerdon). |

In 1937, Hora[4] recorded *D. strigillifer* Myers[5] from Southern India and commented on the discontinuous range of distribution of the species. In the material under report we have all gradations of colour and scale counts and find that the three species mentioned above cannot be distinguished from one another on any reliable character and should, therefore, be regarded as identical. Recently Hora and Law[6] found that the specimens of *Danio* from Travancore were *D. aequipinnatus* and that *D. malabaricus* must be regarded as a synonym of this species. The South Indian specimens of *D. aequipinnatus* grow to a larger size than those found in Northern India.

## **Barbus (Puntius) chrysopoma** Cuvier and Valenciennes.

1878. *Barbus chrysopoma*, Day, *Fish. India*, p. 561.

Under the description of *Barbus pinnauratus*, Day (*loc. cit.*, p. 562) stated that "This form [*B. pinnauratus*] and *B. chrysopoma* may be merely varieties of a single species, while *B. sarana* is closely allied ". According to Day's descriptions of *B. chrysopoma* and *B. pinnauratus*, the two species can be distinguished by the number of predorsal scales — 12 in the former and 10 in the latter. Sundara Raj[7], however, found

[1] Hora, S. L., *Rec. Ind. Mus.* XXXIX, p. 255 (1937) ; *Proc. Nat. Inst. Sci. India* IV, p. 405 (1938).

[2] Hora, S. L. and Mukerji, D.D., *Rec. Ind. Mus.* XXXVI, p. 134 (1934).

[3] Mukerji (*Journ. Bombay Nat. Hist. Soc.* XXXVII, p. 76, 1934) has given reasons to show that Regan's *Danio browni* (*Rec. Ind. Mus.* I, p. 395, 1907) cannot be regarded as a species distinct from *D. aequipinnatus* (McClell.).

[4] Hora, S. L., *Rec. Ind. Mus.* XXXIX, p. 10 (1937).

[5] Myers, G. S., *Amer. Mus. Novitates*, No. 150, p. 1 (1924).

[6] Hora, S. L. and Law, N. C., *Rec. Ind. Mus.* XLIII, p. 243 (1941).

[7] Raj, B. Sundara, *Rec. Ind. Mus.* XII, p. 254 (1916).

that besides other characters there are 10 to 12 rows of predorsal scales in the specimens of *B. chrysopoma* from Madras and remarked :

"The above particulars show that Madras examples combine the characters of the three species, *B. sarana*, H. B., *B. chrysopoma*, C. and V., *B. pinnauratus*, Day, all of which according to the *Fauna of British India* may occur in Madras."

In the limited series of specimens that we have examined, it has been possible to distinguish *B. pinnauratus* from *B. chrysopoma* by the number of predorsal scales, but there seems no doubt that the three species mentioned above along with *B. caudimarginatus* Blyth and *B. sewelli* Prashad & Mukerji form a series of very closely allied species, the specific limits of which are by no means well defined.

### **Nemachilus dayi** Hora.

1935. *Nemachilus dayi*, Hora, *Rec. Ind. Mus.* XXXVII, p. 57.
1938. *Nemachilus dayi*, Hora, *Rec. Ind. Mus.* XL, p. 240.
1938. *Nemachilus dayi*, Das, *Rec. Ind. Mus.* XL, p. 447.

*Nemachilus dayi* is represented in the collection by a large number of young, half-grown and adult specimens. The colouration is very variable. In young specimens the lighter bands are almost as wide as the darker ones and the dorsal and caudal fins are provided with only a few rows of spots. The characteristic colouration of the species is assumed in specimens about an inch and a half in length. From the large series of specimens now examined, it seems that the examples referred by Das (*loc. cit.*, p. 446) and Hora[1] to *N. denisonii* are referable to this species.

### **Amblyceps mangois** (Hamilton).

1933. *Amblyceps mangois*, Hora, *Rec. Ind. Mus.* XXXV, pp. 607-621, text-figs. 1-7.
1940. *Amblyceps mangois*, Hora, *Rec. Ind. Mus.* XLII, p. 374.

The occurrence of *Amblyceps mangois* in the streams of the Hoshangabad District is of special significance. During the survey of the Satpura Trend, it has been collected from all the hilly districts and its range has thus been extended considerably westwards.

The specimens under report are juvenile. The caudal fin is deeply forked and in some the lobes, especially the upper, are greatly drawn out and pointed. The adipose dorsal is relatively short and low.

*Amblyceps mangois* is found along the Himalayas, hills of Assam, Burma, Siam, the Malay Peninsula and the Satpura Trend of mountains.

### **Laguvia ribeiroi** Hora.

1921. *Laguvia ribeiroi*, Hora, *Rec. Ind. Mus.* XXII, p. 741, pl. xxix, fig. 3.
1938. *Laguvia ribeiroi*, Hora, *Rec. Ind. Mus.* XL, p. 179, text-fig. 5.

*Laguvia ribeiroi* was originally described from a single specimen collected from the Khoila River, a tributary of the Tista River in the Jalpaiguri District. Two more specimens of this remarkable catfish were recorded from the Morel River in the Santal Parganas. The occurrence of the species in the Hoshangabad District is of great zoo-

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[1] Hora, S. L., *Rec. Ind. Mus.* XLII, p. 373 (1940).

geographical interest as showing the probable continuity of the Satpura Trend of mountains with the hills of Assam and the Darjeeling Himalayas at a not very distant date.

It has been pointed out by Hora (*loc. cit.*, 1938) that *L. ribeiroi* can be readily distinguished from *L. shawi* by the nature of the dorsal spine which is serrated anteriorly in *L. ribeiroi* and is smooth in *L. shawi*. In the chest region, there are folds of skin which form an adhesive apparatus similar to that found in species of *Glyptothorax* Blyth. Recently, Hora and Gupta[1] described similar corrugations in *L. shawi*.

## SUMMARY.

The collection comprises 40 already known species. A note on the physical features and ecological conditions of the area from which the collection was made is added. Short descriptions of localities with lists of fishes collected from each are also included. A reference is made to the zoogeographical distribution of *Amblyceps* and *Laguvia*, the Eastern Himalayan forms, and of *Parapsilorhynchus*, *Nemachilus evezardi*, *Rita pavimentata*, etc., of the Western Ghats. The significance of the Satpura Trend in the distribution of Malayan forms to Peninsular India is discussed. Notes are appended on *Danio aequipinnatus* (McClelland), *Barbus* (*Puntius*) *chrysopoma* Cuv. & Val., *Nemachilus dayi* Hora, *Amblyceps mangois* (Ham.) and *Laguvia ribeiroi* Hora.

[1] Hora, S. L. and Gupta, J. C., *Journ. Roy. As. Soc. Bengal* (3) VI, p. 5, 1940 (1941).

# RECORDS

of the

# INDIAN MUSEUM

**Vol. XLIV, Part I, pp. 1—14**


## Notes on Fishes in the Indian Museum.

## XLII. On the Systematic Position of the Indian Species of *Scaphiodon* Heckel.

## XLIII. On the Systematic Position of *Cyprinus nukta* Sykes.


By

**SUNDER LAL HORA**



CALCUTTA:

MARCH, 1942

*Reprinted from the Proceedings of the National Institute of Sciences of India, Vol. X, No. 4, pp. 423–439, (1944).*

# ON THE MALAYAN AFFINITIES OF THE FRESHWATER FISH FAUNA OF PENINSULAR INDIA, AND ITS BEARING ON THE PROBABLE AGE OF THE GARO-RAJMAHAL GAP.

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(*Read August 28, 1944.*)

Contents.



## Views of Günther and Day.

In the eighties of the last century, two eminent ichthyologists, Günther (1880) and Day (1885), referred to the geographical relationships of the Indian freshwater fishes and surprisingly enough came to entirely different conclusions. Günther (*loc. cit.*, p. 225) was of the view that 'There exists a great affinity between the Indian and African regions; seventeen out of the twenty-six families or groups [of freshwater fishes] found in the former are represented by one or more species in Africa, and many of the African species are not even generically different from the Indian'. After analysing critically the facts and figures [1] adduced by Günther, Day (*loc. cit.*, p. 317) asserted that 'In India, as restricted, I found 87 genera of freshwater fishes, of which only 14 have representatives in Africa; while among the 369 species of which these genera are composed, only 4 extend to Africa. If we examine the relationships of the same fauna in this restricted Indian area we find, of the 87 genera, 44 extend to the Malay Archipelago, and of the 369 species, 29 [2] are present in both localities'.

The four species stated by Day to be common to the faunas of India and Africa are *Discognathus lamta* (Ham.), *Cyprinodon dispar* (Rüppell), *Gobius giuris* Ham. and *Eleotris fusca* (Bl. and Schn.). The African specimens referred to the first species were found by Boulenger (1901) to be specifically different from the Indian examples and for these he proposed the name *D. blanfordii*. Moreover, the range of *Garra lamta* (Hora, 1921) is now known to be restricted even within the limits of India. *Cyprinodon dispar* is a species of the Middle East; its range extends from round the Red Sea and Persian Gulf to Cutch and North-Western India. The other two species, *G. giuris* and *E. fusca*,

[1] The 'Indian region' of Günther includes: 'Asia south of the Himalayas and the Yang-tse-kiang, and the islands to the west of Wallace's Line', while Day's 'India' includes 'India, Burma and Ceylon'.

It may be noted that Günther's views are based on the distribution of families, while those of Day on the distribution of genera and species.

[2] Repeated checking of Day's lists has convinced me that there are only 22 species of freshwater fishes which are common to the faunas of India and the Malaya region. It is probable that 29 is a misprint for 22.

enter the sea and are, therefore, widely distributed in the Indo-Pacific region. It is thus seen that the four species enumerated above are of little value in establishing any affinity between the freshwater fish faunas of India and Africa. If, however, we compare the lists of genera, as recognised by Day, which are common to India and Africa, and India and Malaya respectively, we get a clear picture of the relationships of the Indian freshwater fish fauna.

*Common to India and Africa.*

1. *Notopterus* Lacép.
2. *Barilius* Ham.
3. *Rasbora* Blkr.
4. *Barbus* Cuv. and Val.
5. *Labeo* Cuvier.
6. *Clarias* Gronov.
7. *Haplochilus* McClell.
8. *Eleotris* Gronov.
9. *Gobius* Artedi.
10. *Periophthalmus* Bl. and Sch.
11. *Ambassis* Cuv. and Val.
12. *Mastacembelus* Cuv. and Val
13. *Discognathus* Hockel.
14. *Cyprinodon* Lacép.

*Common to India and the Malayan region.*

1. *Notopterus* Lacép.
2. *Barilius* Ham.
3. *Rasbora* Blkr.
4. *Barbus* Cuv. and Val.
5. *Labeo* Cuvier.
6. *Clarias* Gronov.
7. *Haplochilus* McClell.
8. *Eleotris* Gronov.
9. *Gobius* Artedi.
10. *Periophthalmus* Bl. and Schn.
11. *Ambassis* Cuv. and Val.
12. *Mastacembelus* Cuv. and Val.
13. *Chela* Ham.
14. *Cirrhina* Cuvier.
15. *Dangila* Cuv. and Val.
16. *Osteochilus* Günther.
17. *Thynnichthys* Blkr.
18. *Acanthopsis* v. Hasselt.
19. *Botia* Gray.
20. *Lepidocephalichtys* Blkr.
21. *Nemachilus* v. Hass.
22. *Homaloptera* v. Hass.
23. *Bagarius* Blkr.
24. *Callichrous* Ham.
25. *Chaca* Cuv. and Val.
26. *Glyptosternum* McClell.
27. *Leiocassis* Blkr.
28. *Macrones* Dumeril.
29. *Pangasius* Cuv. and Val.
30. *Pseudeutropius* Blkr.
31. *Silurus* Artedi.
32. *Wallago* Blkr.
33. *Monopterus* Lacép.
34. *Symbranchus* Bloch.
35. *Nandus* Cuv. and Val.
36. *Pristolepis* Jerdon.
37. *Ophiocephalus* Bloch.
38. *Anabas* Cuvier.
39. *Polyacanthus* Cuv. and Val.
40. *Osphronemus* Lacép.
41. *Mugil* Linn.
42. *Sciaena* (Artedi) Cuvier.
43. *Sicydium* Cuv. and Val.
44. *Rhynchobdella* Bl. and Schn.

As pointed out by Day himself, of the 14 genera of his list common to India and Africa, 12 also extend to Malaya. Of the remaining two genera, *Cyprinodon* is a genus of the Middle East, while *Discognathus* (= *Garra*) is now found to be extensively distributed in south-eastern Asia. Thus, with the exception of *Cyprinodon*, which, as indicated above, has a localised distribution in India, there is not a single genus which is common to the freshwater fauna of India and Africa and is not also found in the Malayan region. The distribution of *Cyprinodon* does not help us to establish any relationship between the faunas of India and Africa.[1] The species and genera common to India and the Malayan region, on the other hand, afford considerable evidence of the Malayan affinities of the Indian fauna.

The following are the 22 (erroneously stated by Day to be 29) species according to Day's lists which are common to the freshwater faunas of India and the Malayan region:—

[1] I have purposely left out of consideration the Cichlid genus *Etroplus* Cuv. and Val. of Peninsular India and Ceylon which has its close allies only in Madagascar. Günther (*loc. cit.*, p. 225) accounted for its occurrence in India as follows:—

> 'Considering that other African Chromides (Cichlidae) have acclimatised themselves at the present day in saline water, we think it more probable that *Etroplus* should have found its way to India through the ocean than over the connecting land area; where, besides, it does not occur.'

I am in agreement with Günther's views concerning the distribution of this remarkable genus.

1. *Notopterus chitala* (Ham.).
2. *Notopterus kapirat* (Pallas).
3. *Rasbora daniconius* (Ham.).
4. *Barbus macrolepidota* (Cuv. and Val.).
5. *Barbus apogon* Cuv. and Val.
6. *Acanthopsis choirorhynchus* Blkr.
7. *Bagarius yarrellii* (Sykes).
8. *Clarias dussumieri* Cuv. and Val.
9. *Clarias magur* (Ham.).
10. *Callichrous bimaculatus* (Bloch).
11. *Pangasius buchanani* Cuv. and Val.
12. *Haplochilus panchax* (Ham.).
13. *Monopterus javanensis* Lacép.
14. *Symbranchus bengalensis* (McClell.).
15. *Pristolepis fasciatus* (Blkr.).
16. *Anabas scandens* (Dald.).
17. *Ophiocephalus micropeltes* Cuv. and Val.
18. *Ophiocephalus striatus* Bloch.
19. *Sciaena coitor* (Ham.).
20. *Eleotris fusca* (Bl. and Schn.).
21. *Gobius giuris* Ham.
22. *Periophthalmus schlosseri* (Pallas).

The above listed species fall into several groups: (i) Derived from marine forms, such as *Symbranchus bengalensis, Sciaena coitor, Eleotris fusca, Gobius giuris* and *Periophthalmus schlosseri*; (ii) Widely distributed in India and the Malayan region, such as *Notopterus chitala, N. kapirat, Rasbora daniconius, Bagarius yarrellii, Clarias magur, Callichrous bimaculatus, Pangasius buchanani, Haplochilus panchax, Anabas scandens* and *Ophiocephalus striatus*; (iii) Restricted to Eastern Himalayas, Assam Hills, Burma and further east, such as *Barbus macrolepidota, Barbus apogon, Acanthopsis choirorhynchus* and *Monopterus javanensis*; (iv) Found in Peninsular India and the Malayan region, such as *Clarias dussumieri, Pristolepsis fasciatus* and *Ophiocephalus micropeltes*. The three species included under group IV, with a discontinuous range of distribution, are of special significance in discussing the relationships of the Indian and Malayan faunas. To this last category can now be added more species (Hora and Law, 1941, p. 240), such as *Barbus (Puntius) burmanicus* Day, *Ambassis thomassi* Day, *Macropodus cupanus* Cuv. and Val., *Mastacembelus guentheri* Day, *Rohtee cotio* var. *cunma* Day (Hora and Misra, 1940, p. 168), etc. These instances leave no doubt regarding some means of continuity at some earlier period between the faunas of Peninsular India and the Malayan region.

If we now examine the genera which in Day's time were only known from within the limits of India, Burma and Ceylon and study their present-day distribution we get some very interesting data. In the list given below, I give 41 such genera with their respective distribution as recorded by Day.[1]

| *Generic Name.* | *Distribution as given by Day.* |
|---|---|
| 1. *Badis* Bleeker .. | India and Burma. |
| 2. *Channa* Gronov. .. | Ceylon and China. |
| 3. *Trichogaster* Bloch. | Upper India, Burma and Siam. |
| 4. *Etroplus* Cuv. and Val. | Western and Southern India, also Ceylon. |
| 5. *Erethistes* Müll and Henle | Orissa, Bengal, Assam, Burma and China. |
| 6. *Rita* Bleeker .. | India and Burma. |
| 7. *Olyra* McClelland .. | Upper Assam and Pegu. |
| 8. *Saccobranchus* Cuv. and Val. | India, Burma and Cochin-China. |
| 9. *Silundia* Cuv. and Val. | India and Burma. |
| 10. *Ailia* Gray .. | Northern India generally. |
| 11. *Ailiichthys* Day .. | Punjab rivers, Ganges and Jumna. |
| 12. *Eutropiichthys* Bleeker | India and Burma. |
| 13. *Amblyceps* Blyth. .. | Himalayas to Burma. |
| 14. *Sisor* Hamilton .. | Indus, Jumna and Ganges rivers. |
| 15. *Gagata* Blkr. .. | India and Burma. |
| 16. *Nangra* Day .. | Sind, Deccan, N.W. Provinces and Bengal. |
| 17. *Euglyptosternum* Blkr. | Syria, the Jumna and Upper Assam. |
| 18. *Pseudecheneis* McClell. | Eastern Himalayas and hills of Assam. |
| 19. *Exostoma* Blyth. .. | Himalayas, Assam, Burma and China. |
| 20. *Belone* Cuvier .. | Marine, some species in freshwater (*B. cancila* mentioned). |
| 21. *Psilorhynchus* McClell. | Bengal and Assam. |
| 22. *Oreinus* McClell. .. | Himalayas and connected mountains in China. |
| 23. *Schizopygopsis* Steind. | Himalayas. |
| 24. *Schizothorax* Heckel. | Himalayas. |
| 25. *Ptychobarbus* Steind. | Himalayas. |
| 26. *Diptychus* Steind. .. | Himalayas. |

[1] The table is made up from Day's lists. For Nos. 1–4, see *Journ. Linn. Soc. London* (Zool.), XIII, pp. 139–143 (1878); for Nos. 5–18, see *ibid.*, pp. 341–344 (1878) and for the remaining genera, see *ibid.*, XIV, pp. 534–579 (1879).

| | | |
|---|---|---|
| 27. | *Semiplotus* Blkr. .. | .. Assam and Chittagong hill-ranges to Burma. |
| 28. | *Scaphiodon* Heckel. | .. Syria, Western Asia, Sind, Punjab and Western Ghats |
| 29. | *Catla* Cuv. and Val. | .. Throughout Northern India, Burma and Siam. |
| 30. | *Amblypharyngodon* Blkr. | .. India, Ceylon and Burma. |
| 31. | *Nuria* Cuv. and Val. | .. India, Ceylon and Burma. |
| 32. | *Aspidoparia* Heckel. | .. India and Burma. |
| 33. | *Rohtee* Sykes .. | .. India and Burma. |
| 34. | *Danio* Hamilton .. | .. India, Ceylon and Burma. |
| 35. | *Perilampus* McClell. | .. India, Ceylon and Burma. |
| 36. | *Somileptes* Swainson | .. Orissa, Bengal and Assam. |
| 37. | *Acanthophthalmus* v. Hass. | .. North-east Bengal, Assam and Burma. |
| 38. | *Apua* Blyth. .. | .. Pegu. |
| 39. | *Jerdonia* Day .. | .. Madras. |
| 40. | *Nemacheilichthys* Day | .. Deccan. |
| 41. | *Amphipnous* Müller | .. India and Burma. |

In the light of our present-day knowledge regarding the systematic position [1] and distribution of these genera, we find that of the 41 genera listed above, *Channa*, *Ailiichthys* and *Apua* are separated from their respective allied genera by the absence of the pelvic fins, but recent work has shown that they cannot be kept distinct from *Ophiocephalus*, *Ailia* and *Acanthophthalmus* respectively; *Euglyptosternum* and *Nangra* are synonyms of *Glyptosternum* (= *Glyptothorax* Blyth.) and *Gagata* respectively; *Jerdonia* and *Nemachilichthys* are endemic to Peninsular India and are found nowhere else; *Oreinus*, *Schizothorax*, *Schizopygopsis*, *Ptychobarbus* and *Diptychus* are essentially Central Asiatic forms, a few representatives of which are found along the southern slopes of the Himalayas and Southern China; *Scaphiodon* is a western genus, the range of which extends to Sind and the Punjab; *Etroplus* is found only in Peninsular India and Ceylon; *Olyra*, *Ailia*, *Sisor*, *Psilorhychus*, *Semiplotus* and *Somileptes* are restricted in their distribution even within the limits of India proper, but show distinct eastern affinities; *Badis*, *Silundia*, *Amblypharyngodon*, *Aspidoparia* and *Amphipnous* are fairly widely distributed in India and Burma; *Erethistes*, *Rita*, *Saccobranchus*, *Eutropiichthys*, *Pseudecheneis*, *Exostoma*, *Catla* and *Rohtee*, besides India and Burma, are either found in Siam, Southern China or Cochin-China or are represented by very closely allied genera in these regions; and *Trichogaster*, *Amblyceps*, *Gagata*, *Belone*, *Nuria*, *Danio*, *Perilampus* and *Acanthophthalmus* are now known from the Malayan region also and with the exception of *Gagata*, a number of Indian species of these genera are also found in the Malayan region.

The above analysis makes two points clear, firstly the very marked Malayan affinities of the Indian fauna and secondly its relationships to the faunas of Siam, Southern China and Cochin-China. We shall have an occasion to refer to these dual affinities of the Indian fauna later (*vide infra*, p. 432).

## VIEWS OF BLANFORD.

After Day, W. T. Blanford (1901) referred to the distribution of freshwater fishes. He gave a list of 79 genera (*Badis*, *Nandus*, *Pristolepis*, *Sciaena*, *Periophthalmus*, *Eleotris*, *Rhynchobdella*, *Mugil*, *Belone*, *Cyprinodon* and *Haplochilus* of Day's lists are not mentioned by him, while *Matsya*, *Akysis*, and *Anguilla*, not mentioned by Day, are included by him. *Matsya* was, however, described in 1888). Blanford divided India, Burma and Ceylon into five subdivisions, which he further divided into 19 tracts. If we refer to his table of distribution of fish genera (*loc. cit.*, pp. 384–387) we find that of the 79 genera listed by him a majority are distributed all over India and, as we know, a number of them extend to the Malayan region also. Some genera are absent only from such specialised zoogeographical tracts as Ceylon or the Himalayas, otherwise they are found all over India. There are also a few genera which have only a restricted distribution even in India, some of them being endemic to one or other of the tracts into which the country is subdivided. From a zoogeographical point of view, such genera as *Scaphiodon*, *Sicydium*, *Pristolepis*, *Homaloptera*, *Silurus*, *Thynnichthys* are of special interest on account of the

[1] In order to facilitate reference to Day's lists, as far as possible, the generic names employed by him are used in this article.

continuous range of their distribution. *Scaphiodon* is a genus commonly met with in Southern Persia, Baluchistan, Sind and the Salt Range, Punjab, but a few species from Peninsular India were referred by Day to this genus. *Sicydium* is known from the Malayan region, Peninsular India and Ceylon; it is a specialised genus of Gobioid fishes and, as it seems to have been evolved from marine ancestors, its distribution is of little value for studying the relationships of freshwater forms. *Pristolepis* is common to Peninsular India and Ceylon on the one hand and to the Malayan region on the other; in fact, one species, *P. fasciatus* (Bleeker), as indicated above, is common to the two regions. *Homaloptera* and *Silurus* are found throughout south-eastern Asia and extend westwards to Burma, Assam and Eastern Himalayas, but their occurrence in Peninsular India is of special interest. *Thynnichthys* is another Malayan genus with representatives in Peninsular India. From the data presented above, it is thus clear that the Malayan fauna extends almost continuously to India as far as the Eastern Himalayas and the hills of Assam, and then some of its very characteristic elements appear in Peninsular India. Though Blanford, in his studies on the distribution of faunas, paid little attention to the distribution of freshwater fishes, he (*loc. cit.*, p. 433) was led to conclude from the distribution of other groups of vertebrates that

> 'The Indo-Malay element in the fauna is very richly represented in the Eastern Himalayas, and gradually diminishes to the westward, until in Kashmir and further west it ceases to be the principal constituent. Almost all the Indo-Malaya genera, and a large proportion of the species, are identical with Assamese and Burmese forms. Theso facts are consistent with the theory that the Indo-Malayan part of the Himalayan fauna, or the greater portion of it, has migrated into the mountains from the eastward at a comparatively recent period. It is an important fact that this migration appears to have been from Assam and not from the Peninsula of India.'

I (Hora, 1938, p. 405) have recently shown in a series of papers that the westward migration of the Malayan element in the freshwater fauna of India did not stop at the Eastern Himalayas, but also spread to Peninsular India from the Assam Hills along the Satpura trend of mountains which stretched across India from the Assam Himalayas to the Gujrat section of the Western Ghats at a not very remote period of the earth's history. We shall, however, deal with this matter later, but attention may now be directed to the advances made in recent years concerning the fish fauna of Peninsular India and their bearing on the zoogeography of this region.

## Recent Advances in the Systematics of Fishes of Peninsular India.

Re-examination of the Peninsular species assigned by Day to the genus *Scaphiodon* Heckel has shown that they are in reality closely allied to *Osteochilus* Günther and are very different from *Scaphiodon* (= *Cyprinion* Heckel). The specific and generic limits of these species have recently been discussed by me (Hora, 1942, pp. 1–10) and I proposed two new subgenera of *Osteochilus* for their reception, namely, *Osteochilichthys* and *Kantaka*. *Osteochilus* is represented by several species in south-eastern Asia and its range extends westwards to Burma. The occurrence of this genus in Peninsular India lends further support to the Malayan affinities of the Indian fauna. It must also be remembered in this connection that the South Indian forms are more closely allied to South Chinese and Siamese forms than to the species found in the Malay Archipelago.

I (Hora, 1942, pp. 10–14) have recently shown that great similarity exists between *Cyprinus nukta* Sykes of the Western Ghats and *Schismatorhynchus heterorhynchus* (Bleeker) of Sumatra and Borneo. Though the two species have been placed in separate subgenera, their close relationship is clear from the structural peculiarities exhibited by them. The distribution of *Schismatorhynchus* is very significant in showing the Malayan affinities of the Peninsular fauna.

Day's *Homaloptera* is a composite genus, but the family *Homalopteridae* as a whole, owing to its specialised features, is of special interest for zoogeographical studies. I (Hora, 1941) have recently described the Homalopterid fishes from Peninsular India and referred them to three genera of the Homalopterinae—*Bhavania* Hora, *Travancoria* Hora and *Balitora* Gray. The first two are endemic to this region while *Balitora* is found in Burma, Assam and Eastern Himalayas on the one hand and Peninsular India on the

other. In fact, the same species, *B. brucei* Gray, is found in both the regions, though it is represented by different varieties in Burma and Peninsular India respectively.

In a revision of the Indian species of *Silurus*, I (Hora, 1936) recognised two forms—*S. cochinchinensis* with two barbels from the Eastern Himalayas, Assam, Burma and further east and *S. wynaadensis* with four barbels from Peninsular India. More recently, however, Bhimachar and Subba Rau (1941) have adduced valuable evidence to show that these two species are conspecific. Thus the range of *Silurus cochinchinensis* now extends throughout south-eastern Asia and the Western Ghats, Peninsular India.

Another important advance has recently been made with regard to the distribution of *Batasio* Blyth by the discovery of a species of this genus from Travancore (Hora and Law, 1941). The geographical range of *Batasio* is similar to that of *Silurus*, and the Peninsular species is not very different from *B. batasio* (Hamilton) of the Eastern Himalayas. Attention may also be invited to the discontinuous distribution of *Mystacoleucus* Günther (Hora, 1937*a*, 1939) which is represented by several species in the Malayan region and by one species, *M. ogilbii* (Sykes), in Peninsular India.

The most remarkable instance of distribution that has come to light recently is that of the occurrence of the Schizothoracine genus *Lepidopygopsis* Raj (1941) in the Periyar Lake in Travancore. As stated above (*vide supra*, p. 426), the Schizothoracinae are essentially Central Asiatic fishes, though a few genera are found along the southern slopes of the Himalayas and in the connected series of hills to the east in Southern China and west in Afghanistan, Seistan, etc. This record establishes a definite relationship of the Peninsular fauna with that of the Himalayas. The Schizothoracinae are not found in the Malayan region.

Attention may also be directed to the occurrence of a globe-fish of the *Monotretus*-type in Travancore (Hora and Nair, 1941). The only other representative of this genus, *Tetraodon* (*Monotretus*) *cutcutia* (Hamilton), is known from Orissa, Bengal and Assam.

Several other specific instances could be cited to show the close relationship between the freshwater faunas of the South Chinese and Malayan regions, and Peninsular India, but I think the above evidence is fairly conclusive on this point. Now the next point for consideration is how this similarity has come about.

## Factors influencing dispersal of Torrential Fishes.

In their evaluation of zoogeographical data, geologists have, as a rule, attached little importance to the distribution of freshwater fishes, for according to Medlicott and Blanford (1879, p. lxvi) 'freshwater fishes and other animals inhabiting rivers and lakes suffer from the serious disadvantage that whilst the exact method by which they or their ova are transported is not clearly understood, there is no doubt that they are capable of being carried alive from one piece of water to another by some natural agency. Hence the limits of their range are imperfectly known'. The above observations may perhaps be true within certain limits in the case of fishes of the plains which live in stationary or slow-moving currents as some of them are adapted to live in waters of low oxygen tension, and some can even live out of water for several hours owing to the presence in them of accessory respiratory organs, but I have referred above to a large number of hill-stream or torrential fishes, about the mode of dispersal of which there cannot be any two opinions. The carps and catfishes of the turbulent waters are very different from those of the plains, and in response to swift currents over rocky substrata have become greatly flattened, almost leaf-like in certain cases, have developed organs of adhesion by which they can stick to rocks like a limpet, have developed mouth-parts for feeding on organic matter encrusting rocks and stones, have reduced respiratory surfaces so that they cannot live in waters of low oxygen tension for any length of time, have lost power of fish-like movements, etc. In view of these structural and physiological adaptations their range of distribution is, as is well known to all students of ichthyology, very limited, for they are not physiologically capable of living in muddy waters or in lakes and slow-moving rivers with soft bottoms. It will thus be clear that if a typical hill-stream fish is found in such widely separated places as the hills of Assam and those of Peninsular India, the drainage of these areas must have had chances to intermingle at some period since the existence

of that species either through earth movements or river captures or both. Owing to their very limited power of migration, torrential fishes afford better evidence of zoogeographical relationship.

### Geological Age of the Fish faunas under consideration.

It is worth remembering that the fish faunas of the two regions are, generally speaking, not of any great age, for the Ostariophysi, comprising carps and catfishes, did not appear till the commencement of the Tertiary period and the highly adapted torrential forms met with to-day must have appeared much later, probably under the impetus supplied by the last phases of the orogenic movements that gave birth to the Himalayas. This mighty chain of mountains is now generally believed to be the result of at least three major mountain-building movements, all of which occurred during the post-Eocene period. By that time the present-day dominant class of bony fishes had already appeared.

### Explanations of Malayan Affinities of the South Indian Fauna.

Leaving out of consideration the possibility of any natural agency transporting torrential fishes or their ova from the Eastern Himalayas to the hills of Peninsular India, three views have been advanced to account for similar facts of distribution concerning the flora and terrestrial animals, such as mammals, birds, reptiles, etc. The oldest of these is the supposed direct land connection between the Malayan region and South India, but we now know that the Bay of Bengal is a very old feature of the physiography of India and that it existed in its present position, though in a somewhat modified form, throughout the Tertiaries. In the present state of our knowledge of the geology of India, this view is untenable.

Medlicott and Blanford (*loc. cit.*, pp. 374, 375) have regarded the similarity in the fauna and flora of the Malayan region and the Himalayas to those of South India as an evidence in favour of the effect of the glacial epoch of Peninsular India. They have stated as follows:—

'On several isolated hill ranges, such as the Nilgiri (Neilgherry), Animale (Animullay), Shivarai (Shevroys), and other isolated plateaus in Southern India, and on the mountains of Ceylon, there is found a temperate fauna and flora, which does not exist in the low plains of Southern India, but which is closely allied to the temperate fauna and flora of the Himalayas, the Assam range (Garo, Khasi, and Naga hills), the mountains of the Malay Peninsula and Java. Even on isolated peaks, such as Parasnath, 4,500 feet high, in Behar, and on Mount Abu in the Aravali (Aravelli) range, Rajputana, several Himalayan plants exist. It would take up too much space to enter into details: the occurrence of a Himalayan plant like *Rhododendron arboreum*, and of a Himalayan mammal like *Martes flavigula* on both the Nilgiris and Ceylon mountains will serve as an example of considerable number of less easily recognised species. In some cases there is a closer resemblance between the temperate forms found on the peninsular hills and those on the Assam range than between the former and Himalayan species, but there are also connections between the Himalayan and peninsular temperate regions which do not extend to the Eastern hills. The most remarkable of these is the occurrence on the Nilgiri and Animale ranges and on some hills further south of a species of wild goat, *Capra hylocrius* belonging to a sub-genus (*Hemitragus*), of which the only other known species, *C. jemlaica*, inhabits the temperate region of the Himalayas from Kashmir to Bhutan. This case is remarkable, because the only other wild goat found completely outside the Palaearctic region is another isolated form on the mountains of Abyssinia.

'The range in elevation of the temperate fauna[1] and flora of the Oriental region in general appears to depend more on humidity than temperature, many of the forms, which, in the Indian hills, are peculiar to the higher ranges, being found represented by allied species at lower elevations in the damp Malay Peninsula and Archipelago, and some of the hill forms being even found in the damp forests of the Malabar coast. The animals inhabiting the Peninsular and Ceylonese hills belong, for the most part, to species distinct from those found in the Himalaya and Assam ranges, etc.; in some cases even genera are peculiar to the hills of Ceylon and Southern India, and one family of snakes is represented elsewhere. There are, however, numerous plants and a few animals inhabiting the hills of Southern India and Ceylon which are identical with Himalayan and Assamese hill forms, but which are unknown throughout the plains of India.

'That a great portion of the temperate fauna and flora of the Southern Indian hills has inhabited the country from a much more distant epoch than the glacial period may be considered

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[1] Evidently reference is here made to the terrestrial fauna, such as birds, mammals, insects, etc. The distribution of aquatic fauna is obviously governed by other equally important factors.

as almost certain, there being so many peculiar forms. It is possible that the species common to Ceylon, the Nilgiris, and the Himalayas may have migrated at a time when the country was damper, without the temperature being lower, but it is difficult to understand how the plains of India can have enjoyed a damper climate without either depression, which would have caused a large portion of the country to be covered by sea, a diminished temperature which would check evaporation, or a change in the prevailing winds. The depression may have taken place, but the migration of animals and plants from the Himalayas to Ceylon would have been prevented, not aided, by the southern area being isolated by sea, so that it may be safely inferred that the period of migration and the period of depression were not contemporaneous. A change in the prevailing winds is improbable so long as the present distribution of land and water exists, and the only remaining theory to account for the existence of the same species of animals and plants on the Himalayas and the hills of Southern India is depression of temperature.'

These views have been quoted by Wadia (1939). Sir C. S. Fox has informed me that there is no actual evidence in Peninsular India of any glacial period of the tertiary or later times. There is evidence, however, that during the glacial period the glaciers extended far below their present limits in the Himalayas and Karakoram, and, in consequence, the temperature must have been much lower both in the Himalayas and in the Peninsula. This low temperature probably influenced the distribution of terrestrial fauna southwards, but in the case of aquatic animals, especially torrential fishes, it is difficult to understand how they could cross physical as well as physiological barriers of the nature stated above even when the temperature became greatly depressed in the country between the Himalayas and the hills of Peninsular India. Moreover, in view of the large number of forms that are common to the two regions, it is rightly presumed by Medlicott and Blanford that the peculiar forms of South India may have been established there even before the commencement of the glacial period during the Pleistocene in the northern regions.[1]

In 1937, while discussing the distribution of Himalayan fishes and its bearing on certain palaeogeographical problems, it was stated by me (Hora, 1937, p. 255) that

'This differential movement which probably occurred late in the Miocene period, must have obliterated all traces of the eastward extension of the Indobrahm and also acted as a barrier between the eastern and the western Himalayan fishes. The new stocks of specialised hill-stream fishes from the east, not finding means to cross this barrier, were deflected towards south-west along the Satpura Trend which probably at this period stretched across India as a pronounced range from Gujarat to the Assam Himalayas. From Gujarat the hill-stream fauna migrated towards the south along the Western Ghats and spread to the hills of the Peninsula in the extreme south.'

## Recent Surveys of the Fish fauna of the Satpura Trend.

In view of the interesting findings referred to above, zoological surveys (Hora, 1938, 1940, 1941; Das, 1939) were carried out of the Rajmahal Hills, Santal Parganas, Hazaribagh Hills, the headwaters of the Mahanadi River in the Raipur district and Pachmarhi, Hoshangabad district, the highest point of the Satpura Mountains, to test the hypothesis advanced by me. Dr. H. Crookshank of the Geological Survey of India very kindly made a collection for me in the Bailadila Range, Bastar State. These collections have already thrown considerable light on the distribution of fishes along the old Satpura trend. Before considering the evidence provided by the fresh material, it must be borne in mind that the hills referred to above are mere stumps of a once more highly elevated country with many perennial torrential streams running down its slopes. At the present time most of the streams either dry up altogether or are reduced to a mere trickle in the dry season. Under the ecological conditions prevailing to-day in these hills, the presence of typical torrential forms, which require a continuous flow of water over a rocky bed, is not to be expected, but the presence of *Laguvia* in the Rajmahal Hills and the Hoshangabad district and of *Amblyceps* in all the regions so far studied by the Zoological Survey is of special significance; both the genera live in sub-mountainous streams where during the dry season they seek shelter in pools or under wet rocks. The genus *Laguvia* was proposed by me for two small catfishes of the Teesta River and a species from Southern China was also referred to this genus. From the Rajmahāl Hills and the Satpuras one of the Teesta River

[1] For recent information on this subject reference may be made to H. de Terra and T. T. Paterson 'Studies on the Ice Age in India and associated human cultures' (Washington, 1939).

forms has been obtained and it shows that the Garo-Rajmahal gap probably came into existence at a not very remote period of the earth's history. Before the zoological survey of the Rajmahal Hills, *Amblyceps mangois* (Hamilton), the only species of the genus, was known from the Himalayas, the hills of Assam, Burma and Siam. Its range has now been extended to the Hoshangabad district in the west and the Malay Peninsula in the east. The results of the zoological survey of the various sections of the Satpura trend clearly indicate that at some remote period the fauna of this chain of hills had some means of continuity with that of the hills of Assam.

## Geological Age of the Garo-Rajmahal Gap.

At what period of the earth's history the Satpura Mountains became reduced to their present position and when the Garo-Rajmahal gap became a feature of the physiography of India, it is not possible for me even to conjecture, since the geological views are so conflicting regarding the age of the gap. The following sequence of events is, however, partly suggestive of the changes undergone by this region. Geologically it is an established fact that the Shillong plateau in Assam is merely a severed portion of the Peninsular region which has been isolated by the alluvium of the lower Ganges and Brahmaputra. In the Gondwana times the flow of rivers was north-west across the present Satpuras (Fox, 1937), and the fish fauna of the Intertrappean beds at Deothan and Kheri in the Central Provinces (Hora, 1938*a*) also shows that the survivors of the Gondwana north-west drainage persisted across the range at least until the time when these beds were laid. Dunn (1939) has shown that contemporaneous with the orogenic movements of the Himalayas there were definite uplift movements, though of a different nature (block types), in the northern part of the Peninsula. He has concluded that:

> '1. An early Tertiary peneplain, uplifted 1,000 feet to the south and with a tilt to the north-east. It is represented by the Neturhat and other plateaux, residuals above the present Ranchi plateau, whilst the Rajmahal hills are also representative of its north-eastern corner.
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> '2. A further uplift of perhaps 1,000 feet sometime between middle and late Tertiary, reaching a maximum in the Ranchi plateau and its dissected extension to the south. This uplift was in the nature of a tilt to the north and north-east from the Hazaribagh plateau, but at the Son river the northern edge of the upwarp was more abrupt. On the eastern side the upwarp was also abrupt.
>
> '3. Further south, after an interval sufficient to permit the formation of quite a well-defined peneplain, a further uplift of 300 feet took place with at least a sharp upwarp in the Subarnarekha region.
>
> '4. A gradual further rise in the south and also along the east coast, amounting to 400 feet, down to the present day.
>
> 'It is apparent, then, that the Tertiary period has been one of no inconsiderable movement in this part of the Peninsula, although not on the same scale as in the Himalaya. The type of movements in the two areas were vastly different, however, for on the Peninsula they were of the block type.
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> 'To the south of Chota Nagpur the upward movements were cumulative, whereas further north, close to the edge of the Gangetic alluvium, and particularly around the Rajmahal hills, there was no apparent differential movement—there may have been subsidence, but certainly not uplift.'

It is known that the orogenic movements that gave birth to the Himalayas changed the physiography of India to a very marked extent and these movements are believed to have been most intense during the Miocene period. In the beginning the uplift movement was probably of uniform intensity along the whole length of the Himalayas, but later it probably became more marked in the region of the isthmus comprising the western part of the Assam Himalayas and the eastern part of the Nepal Himalayas, as practically all the highest peaks are clustered round this area. This differential movement, which probably occurred late in the Miocene period, produced some impenetrable barriers between the eastern and western Himalayan fishes. It was probably after this that the new stocks of specialised hill-stream fishes from the east were deflected towards the south-west along the Satpura trend. On the assumptions made above, it seems reasonable to presume that the Garo-Rajmahal gap was non-existent at some period after the Miocene, for the fishes referred to above are so 'modern' that it is difficult to assign them to a Geological 'Victorian' age. However, in a recent publication of the Geological Survey of India, Krishnan and Aiyengar

(1940) have concluded that there is every probability that the second phase of the Himalayan upheaval of Middle Miocene age broke down the barrier across the Garo-Rajmahal region. After discussing the Miocene transgression of the Bay of Bengal, they made the following observations on the age of the Garo-Rajmahal depression:

'If, however, we look into the structure of the Shillong Plateau, we notice that it has been subjected to movements from two sides, one from the north by which overthrust faults have been developed and one from the east producing extensive block-faulting, the blocks being bounded by north-to-south faults. The portion of the old ridge between the Rajmahal hills and the Garo hills appears to have been depressed during the period, probably by the downward block-faulting or by buckling, because of the thrust from the east. The cause envisaged here is quite adequate for producing the gap in question, and it should be pointed out that no such convincing tectonic cause is available at a later age to explain the formation of the depression. Moreover, if the gap were of post-Pliocene age as thought by Pascoe, the topography of the region would be decidedly less mature than it is, as pointed out by C. E. N. Bromehead in the discussion of Pascoe's paper before the Geological Society of London. Bromehead has stated (*Quart. Journ. Geol. Soc.*, **75**, p. 156, 1919):

"If the lower course of the Ganges and the Brahmaputra was also of recent date, and due to the cutting-through of a hard ridge joining the Indian Peninsula to the Assam Hills, one would expect a gorge similar to that of the Indus instead of the broad open valley which, on the map, had all the appearance of mature age."'

I am in no way competent to discuss the geological evidence adduced above, but the type of fishes that seem to have crossed over the Satpura trend before this depression in its present form came into existence do not seem to be of Miocene age. Further, Dunn (*loc. cit.*, pp. 137–142) has shown that 'the Tertiary period has been one of no inconsiderable movement in this part of the Peninsula although not on the same scale as in the Himalaya'. Thus, it is certain that even in post-Pliocene times block-faulting occurred in the Peninsula and the Garo-Rajmahal gap may be the result of these later block-faulting. The distribution of fishes, however, supports a Pleistocene age of the gap as advocated by Oldham (1893, 1894), Pilgrim (1919) and Pascoe (1919).

## Origin and Dispersal of the Fish fauna of South-east Asia.

In discussing the distribution of fishes, I have assumed that the peculiar forms of South India are migrants from Southern China, Burma, Assam Hills and Eastern Himalayas. There is strong zoological evidence in support of this. As indicated above the home of the Homalopteridae is in south-eastern Asia and the hills of South India, where the family is represented by three genera, are only an outpost in its range of distribution. The same is true of *Silurus*, *Batasio*, *Thynnichthys*, etc. Recently Dr. B. Sundara Raj (*loc. cit.*) discovered a remarkable genus of *Schizothoracine* fishes in Travancore. His new genus is closely allied to *Schizopygopsis* Steindachner, but like the South Indian Homalopterid genera, *Bhavania* and *Travanoria*, it has also several interesting features not met with in any other member of the family. They indicate that long isolation from the parent stock has induced special modification in them to meet the requirements of their new habitats.

The spread of fishes from north-east to south-west over the Miocene Satpura trend seems to have been facilitated by the upheaval movements of the late Miocene and later periods. I have referred above to the differential movements that produced the high peaks of the Sikkim Himalayas, prevented the migration of torrential fishes to the western parts of the range and deflected it along the Satpura trend. As pointed out by Krishnan and Aiyengar, these movements were from two sides, one from the north and one from the east. The thrust from the east probably produced a downward block-faulting and buckling in the Satpura trend and thus made it possible for the north-eastern fishes to spread to south-west. Gregory and Gregory (1923) in their work on 'The Alps of Chinese Tibet and their Geographical Relations' and Gregory's (1925) studies on 'The Evolution of the River System of South-Eastern Asia' have also shown that from Yunnan south-westwards the rivers on the west beheaded the rivers on the east. There is a considerable amount of zoogeographical evidence based on the distribution of hill-stream and other freshwater fishes which shows that the fish fauna of India probably migrated from the South Chinese territory. The close similarity of the faunas of the Peninsula of India with that of the Malay Peninsula seems to be due to the simultaneous migration of the

primitive forms in these remote corners from a common ancestral stock and not to any exchange of faunas *inter se.*

The peculiar distribution of the so-called Malayan forms, which occur equally extensively in South China, Cochin-China, Siam and Burma, within the limits of India proper—the Assam hills and the Darjeeling Himalayas on the one hand and the hills of Peninsular India on the other—can be accounted for on the assumption that the Satpura trend extended as a fairly pronounced and continuous ridge between the Assam Himalayas in the east and the Gujarat portion of the Western Ghats in the west even up to, geologically speaking, recent times. It has to be inferred, therefore, that the gap, as we find it to-day, is in all probability a very recent feature of the physiography of India, and this view is strongly supported by the distribution of the specialised types of fishes referred to above.

## Summary.

After discussing the views of Günther, Day and Blanford regarding the probable affinities of the freshwater fish fauna of India, the author deals with the recent advances in the systematics of fishes of Peninsular India. The factors that influence the dispersal of torrential fishes are elucidated, and the probable geological age of the fish fauna under consideration is given. From the data thus collected, it is pointed out that the fish fauna of Peninsular India shows strong Malayan affinities. This conclusion is further strengthened by the surveys of the fish fauna of the Satpura trend of mountains and after discussing the available geological evidence the author concludes that the Garo-Rajmahal gap must be of recent origin, as a continuous range across the gap must be presumed for the dispersal of Malayan fauna along the Satpura trend. Attention is then directed to the probable origin and mode of dispersal of the fish fauna of South-east Asia.

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## DISCUSSION.

The Chairman thanked Dr. Hora for his paper, and considered that the evidence he had brought forward regarding a land connection, capable of supporting torrential streams, between the Burma-Malayan area and Peninsular India, was of great interest. He called upon any Fellows or visitors present to express their views.

Capt. A. N. Thomas stated that he had listened to Dr. Hora's paper with much interest, and had the following comments to make.

As regards the migration of freshwater fishes, interest centres chiefly around the migration of carps and catfishes such as the genus *Laguvia* and especially of the species able to live only in turbulent water and said to be common to the Teesta valley and the Satpura ranges. Dr. Hora states that some of the carps and catfishes can live only in turbulent waters and are incapable of living in muddy waters or lakes and slow-moving rivers with soft bottoms. It may be asked, however, whether the ova and larvae of these specialised fishes are similarly restricted. If not, migration could have taken place through muddy or slow-moving streams before the individuals reached maturity. It is known that the ova of catfishes are demersal and that they are frequently firmly attached to rocks, etc., and that in the larval stages they are subjected to parental care. These characteristics are against migration of the young independent of their parents. Nevertheless a study of the early life history might show that migration across muddy waters is possible in extreme youth.

A second possibility is dispersal by meteorological means. Fertilised ova and/or larvae could be caught up by violent cyclonic storms over the Assam Himalayas and descend as 'rains of fishes' on the Satpuras or other parts of Peninsular India. Admittedly this is not the normal direction of the paths of cyclonic storms over this part of India, but meteorological conditions in the past may not always have been as they are at present.

And now as regards the Garo-Rajmahal Gap and the Satpura trend. The latter, described by Sir Lewis Fermor as the 'Satpura protaxis', does not appear to correspond with any well-defined structural line. The hill regions referred to this trend are composed of many diverse stratigraphic and structural units. The Shillong Plateau appears to have no real connection with this trend. As pointed out by Sir Cyril Fox, it originated due to forces coming from the forward thrust of the Himalayas.

The Rajmahal Hills are formed of gently dipping beds of lava (Rajmahal trap) of ? Jurassic—? Cretaceous age. There is no sign of any orogenesis, following the Satpura trend, affecting the Rajmahal trap. This formation maintains a general N.-S. strike with a gentle regional dip to the east, in which direction it passes under the Ganges alluvium. The Cretaceous, Eocene and Miocene of the Shillong area dip southwards

off the Shillong Plateau at Sylhet and Cherrapunji but further west the trend of the outcrop swings round to a north-west to south-east strike with a regional dip to the south-west.

These facts indicate that there has been no axis of folding along the E.-W. Satpura trend since the Jurassic (Rajmahal trap) period. There has however been subsidence along a north-south axis between the Garo and Rajmahal Hills. Whether this subsidence is due to block faulting or regional warping is uncertain, as there is no direct evidence.

At the south-western end of the Garo Hills the marine Sylhet limestone passes into shore-line conditions while the underlying Cherra sandstones are estuarine. The overlying Kopili beds are marine and above these, separated by an unconformity, there is marine Miocene. The occurrence of these beds to the west of Tura, whether estuarine or marine, indicates that the Garo-Rajmahal area was at a low level in late Cretaceous and early Eocene times. The area was not invariably covered by the sea but the shore line in the Garo Hills in lower Eocene times was already half-way through the gap and in any case estuarine and fluviatile deposits are evidence of relative low level. It should be noted that at this time the Shillong Plateau did not exist as a physiographic high. According to Sir Cyril Fox it came into existence in the Miocene period under the influence of the forward thrust of the Himalayas. The Garo-Rajmahal Gap was probably not uplifted to any extent but remained throughout the Miocene as a physiographic and structural depression, which may or may not have been invaded by the Miocene sea.

The Garo-Rajmahal Gap is thus regarded as a very old and persistent feature which has been at a low level continuously from at least late Cretaceous or early Eocene times.

If a watershed connecting Peninsular India with the Assam Himalayas in post-Miocene times is necessary to explain the migration of torrential fishes there must have been some alternative to the Garo-Rajmahal line. It is suggested that this could have been along a zone between the Monghyr and Rajmahal Hills on the south and the Darjeeling and Eastern Nepal Himalayas on the north. The north-south trend of the Dharwar rocks at Monghyr and the similar strike of the Rajmahal hills lends colour to this view. The Teesta at this time could have flowed through the Rajmahal-Garo Hills Gap, renewed subsidence of which gave it additional cutting power and enabled it to capture the Ganges and Brahmaputra drainage, at a later date.

The above suggestions seem to fit all the known facts and the Monghyr-Himalaya connection seems more probable than the Garo-Rajmahal connection. Additional stratigraphical and structural work is, however, necessary to prove the theory.

Mr. J. B. Auden considered that as far as geologists are concerned, there is little that can be discussed. He thought that the geological evidence in this problem was still very hazy, and lacked the factual certainty of the faunal evidence.

Dr. Hora, after reviewing the available geological evidence, is led to the following sequence of events:—

(1) Formation of Garo-Rajmahal Gap in M. Miocene times; this partly on the evidence of the Miocene marine forms in the Darjeeling foothills, partly because of a paper by Krishnan and Aiyengar.

(2) Closing of the gap to allow for migration of freshwater torrential fish. The closure must have been about Pliocene.

(3) Final formation of the gap in Pleistocene times.

I know nothing about the evidence of the Miocene sea extending up to the Darjeeling foothills, except from a talk with Dr. Fox, who seemed uncertain where the fossils of marine type came from. There may have been marine conditions, with an arm of the sea extending through a gap between Garo and Rajmahal, but it should be stressed that the evidence depends on the uncertain location of fossils.

Krishnan and Aiyengar are wrong in my opinion in supposing that the Garo-Rajmahal Gap must be Miocene because 'it should be pointed out that no such convincing tectonic cause is available at a later age to explain the formation of the depression'. Quite apart from the evidence adduced by Dr. Dunn in the Bihar-Nepal earthquake memoir for movements in the Peninsula, the mere fact that the Siwalik rocks from the Punjab to Assam are highly folded and dislocated by thrusts indicates there were strong movements

in late Pliocene or Pleistocene times. If there was strong folding in the Himalayan Siwaliks there could certainly have been strong block faulting in the Garo-Rajmahal region.

Granted, however, that a gap may have existed in Miocene times, it may be doubted if it would close again to form a ridge adequate for migration of torrential fish by mere filling up, as suggested by Dr. Hora (p. 431). The block-faulting, which formed the gap, took place in ancient 'Crystallines', the Archaean foundation to Peninsular India. To close it again and form a moderately high ridge would imply rather the reversed block-faulting to that which is supposed to have formed the gap in Miocene times. The cork was extracted, so to speak, and put neatly back into the bottle at a later date. It is even more difficult to imagine soft Pliocene sediments, just laid down in the supposed gap, being conveniently elevated into a range with the same strike as the present east-west Shillong-Garo range. True, the Siwaliks are elevated to ranges in the Himalayan foothills, but it is difficult to imagine the same process taking place in the gap, formed by block faulting along faults with presumably a north-south trend. For this would imply the re-introduction of movements of an orogenic type in a region which had only just previously been subjected to block faulting. While such a change-over would not be impossible, it is at least improbable.

Both from the point of view of the crystalline cork being pushed up into the same place it had formerly occupied, and from that which supposes Pliocene sediments to have formed a range between the Garo Hills and the Rajmahals, it is difficult really to imagine that the gap, once formed, should have been blocked again.

It would seem possible, therefore, that the gap never originated until the Pleistocene, and that the migration of torrential fish faunas proceeded unimpeded until then. This conclusion may be vitiated if it is truly established that marine Miocene faunas did spread northwards to the Darjeeling foothills, but I should hesitate at present to regard this as more than a possibility. More work is, in fact, required on the Siwaliks of Darjeeling district.

Dr. Hora has stated:

> 'In the beginning the uplift was probably of uniform intensity along the whole length of the Himalayas, but later it probably became more marked in the region of the isthmus comprising the Assam Himalayas and the eastern part of the Nepal Himalayas, as practically all the highest peaks are clustered round this area.'

I don't think we have much evidence that the uplift was ever of uniform intensity. With regard to the clustering of high peaks, it is true that there is a cluster between Everest and Kangchendzonga, but there is also a cluster of high peaks, such as Kamet and Nanda Devi, in the Kumaon. To what extent such clusters represent elevations along axes at right angles to the Himalayan trend, with the consequent prevention of migration of faunas, is still almost unknown. The post-thrust warps, with denudation on the secondary anticlines, which resulted in denudation down to the Daling slates and phyllites underlying the Darjeeling Gneiss, seem to have no relation to the clusters of peaks. In fact, Kangchendzonga appears to lie along the secondary syncline which lies between the Tamur River anticline and the Teesta anticline (*Rec. Geol. Sur. Ind.*, LXIX, plate 8, 1935). Much more work has to be done before we can attempt to be sure of the relation of peak clusters to the sequence of earth-movements.

Dr. J. A. Dunn stated that in referring to his views he would have preferred to see a reference to the later *Memoirs*, LXIX and LXXVIII, in which more particular reference is made to this part of the Peninsula.

He agreed broadly with much of what Messrs. Auden and Thomas had said. The north-south strike of the Archaean rocks at Monghyr—a strike infinitely older than the movements under discussion—should have no significance in this context. But, even so, Mr. Thomas was right in drawing Dr. Hora's attention to the possibility of a connection between this north-east corner of the Peninsula and the Himalaya.

He referred to *Memoirs*, LXXVIII, pp. 8-9, 13 and 14, in which this part of the Peninsula is described as a hinge-zone, the focus of the hinge creeping south. He could well picture that the hinge-zone in mid-Tertiary was close to the Himalaya, and that the southerly migration of this focal point had been responsible for the great width of the

Gangetic alluvium. Many of the streams from the scrap just to the south of the hinge-zone were torrential in character and their ancestors to the north would have provided the conditions required by Dr. Hora.

He stated that in *Memoirs*, XXVIII, pp. 8, 12 and 14, he had briefly reviewed the evidence of the Rajmahal Hills which *on their eastern side* again form a hinge-zone between the Gangetic plains to the north-east and the Peninsula to the south-west. He made the categorical statement that 'these lavas can never have been uplifted (i.e. to the extent of hundreds of feet as in the country to the south-west) . . . . . , they may have suffered depression'. Here again the westerly migration of this hinge focus from close to the Garo Hills to its present position during the latter part of the Tertiary is not improbable. But nowhere along the eastern side of the Rajmahal Hills is there any sign of a sudden downwarp such as occurs further west in Monghyr, Hazaribagh and Gaya, and nowhere is there a suggestion of torrential streams in this eastern direction.

The whole aspect of the Rajmahal traps and the Tertiaries to the south is against the idea of a convenient uplift and depression of a ridge postulated by Dr. Hora. The Rajmahal traps have a persistent easterly dip with no noticeable east-west rolls, and the Tertiaries cannot be said to show any noticeable disturbance.

Although in Mayurbhanj the Tertiaries are marine (in part at least), in Singhbhum—Midnapore—Bankura they are estuarine and fluviatile. He would like to see them mapped carefully from Mayurbhanj to the Rajmahal Hills. Although the present north-south strike of the western edge of the Tertiaries is probably in part due to deposition on an east-sloping land surface, it is possible that they have received an actual easterly dip as would be suggested not only by the dip of the Rajmahal traps but also by the gentle warps which we have detected in this part of the Peninsula. There is consistent evidence of depression to the east, but no evidence of an east-west ridge connecting the Rajmahal and Garo Hills in mid-Tertiary times.

Sir Cyril Fox stated that as regards the marine Miocene fossils from the Teesta valley above Sivok, he sent Mr. V. P. Sondhi to search the exposures where Mallet was supposed to have found the fossils, but this search was unsuccessful. He knew the area and could not think of a likely place to search between Sivok and the Kalapani bungalow. All he could say now was that a search had failed to locate the fossil horizon said to have been found by Mallet. This puts the extension of the Bay of Bengal northwards in Miocene time to a limit not further north than the South Rajmahal Hills. He thought it would clear matters if he gave a résumé of the geological evidence known to him from the close of the Cretaceous in the Assam-Bengal region.

Lower Gondwanas occur in the Garo Hills near Singamari (Hallidaygunj) and in the Assam Himalaya, but there is no evidence of any Upper Gondwanas in either region as the next newer strata are marine Cretaceous in the Khasi Hills near Cherrapunji. Overlying the Cretaceous and overlapping northwards on to the main Assam plateau are the Cherra sandstones (really arenaceous limestones in the type section) with the coal seams of the Garo Hills and north of Shillong. These Lower Eocene strata are believed to be estuarine as some marine fossils were found in an outlier by Mr. A. M. N. Ghosh. The next beds are the Sylhet limestones which definitely pass into a shore line series near the south-western corner of the Garo Hills. Above these limestones come the Nongkulong or Kopili beds also marine and conformably above the Sylhet limestones. A stratigraphical 'break' evidently occurs above the top of the Kopilis (Siju-Rewak shales and sandstones) in the Garo Hills. The next fossiliferous strata are the Baghmara-Dalu beds, also marine, of Miocene age. These strata are in force in the south of the Garo Hills and continue to the south-west but no marine fossils have been found in the south-west area yet. Miocene beds with marine to estuarine fossils occur in Mayurbhanj near Baripada. It is thought that the 400 odd feet of stratified soft rocks under the laterite of Khargpur are possibly Miocene, and it has been suggested that the beds immediately under the laterite west and north-west of Burdwan are of the same Miocene age. This is also believed true of the so-called older alluvium under the laterite of the Madhupur Jungle, of the Barind of Rajshahi and in the area about Suri south of the south end of the Rajmahal Hills. Except for fossil wood no other fossils have been found under or with the laterite of the places

named. There is no evidence for the certainty of marine beds of Miocene age except in the Garo Hills and in Mayurbhanj. So much for stratigraphy.

As regards the distribution of land and sea, it is evident that the Cretaceous sea in southern Assam was followed by shallow estuarine or marine lagoons over what is now the Assam plateau or range. This was succeeded by a clear sea in the area of the Khasi and Jaintia Hills. This Nummulitic sea extended up to the Mikir Hills and westwards to the south-west Garo Hills where it was definitely shallow as no real limestones occur here and the beds are thin compared with the section near Therria Ghat south of Cherrapunji. No Eocene strata have been found in the Bengal region although such beds indicating estuarine conditions occur north of the Barail Range and in Upper Assam near Tipongpani. Such beds occur of course in Upper Burma indicating estuarine to gulf conditions outwards in that region in Eocene times. We have no evidence of any 'gap' between the Rajmahal Hills and the Garo Hills up to the Miocene period, but there was sea over southern Bengal from Mayurbhanj to the south-west corner of the Garo Hills in Miocene times. The laterite of Midnapur, of Madhupur (Jungle) and south-eastwards from the Rajmahal Hills suggests that there was no 'gap' even at the time of the so-called Older Alluvium. This lateritic material, of the Madhupur Jungle, the 'barind', and in Midnapur is believed to be of Pleistocene age, but this is an assumption without any proof whatsoever. Laterite of the same kind occurs in the north-west corner of the Garo Hills and near Goalpara. He believed some of the lateritic material found in the 'tilas' of Sylhet and in the Cachar and Tippera Hills was also of the same age—probably between Upper Miocene and Pleistocene but this merely indicated that the land was probably more elevated and better drained during the above period and did not establish any exact geological age.

From a study of the evidence in his possession he would say that the sea had begun to fall back from the Assam plateau area in upper Eocene times. However, marine conditions persisted in the southern Assam region up to and involving the southern parts of the Garo, Khasi and Jaintia Hills up to the close of the Eocene epoch, and even after that, during the Miocene epoch marine conditions were present over the region from the Garo Hills to Mayurbhanj. After this there was some elevation of the land from Orissa and eastern Bihar through the Rajmahal area round to the Garo Hills and Eastern Bengal. The Assam plateau came into existence in Miocene times and has continued to develop since. The Sylhet limestones are in a monoclinal fold south of Cherrapunji. In the Garo Hills they are overfolded and thrust over from the north. The Garo Hills are sliced by northward trending faults which are newer than the Miocene beds. It is recognised that the forces involved have come from the uplift of the Himalayas—a push southward to make the Assam area a bow wave, and a thrust from the Naga-Arakan folding from the east. These two forces fully explain the folding and faulting encountered in the Assam region. Their combined effect while explaining the Assam plateau can equally well explain the 'gap' between the Rajmahal and Garo Hills. It is structurally a sag which may or may not be accompanied by faulting. He was inclined to favour some axis of special depression, because the rivers—the Teesta, the Brahmaputra and the Ganges—have altered their courses to adjust along a special axis of depression. He thought it may be accepted that the 'gap' is relatively recent and that faulting and subsidence have continued and are almost certainly still in progress. This would make the 'gap' begin at the same time as the rise of the Assam plateau—in Miocene times, although it may not have immediately allowed the Ganges and Brahmaputra through—possibly not till very much later. He did not believe in the Indo-Brahm of Pilgrim or Pascoe except as a depression parallel with the Himalaya in which a string of lakes and marshes existed, but certainly no river with a continuous flow in a westerly direction. He believed the Brahmaputra came through the saddle in the north Cachar Hill and that when the 'gap' developed the Ganges string of lakes and those of the Assam valley were gradually but separately drained and the rivers formed, and then the Brahmaputra was 'captured' and the Ganges defined and developed,—all since the close of the Tertiary era, and that these operations have been guided by the folding and faulting which seems to have continued, particularly since the Pleistocene until now.

During the course of his remarks, Professor S. P. Agharkar stated that the data presented by Dr. Hora regarding the discontinuous distribution of Indian freshwater fishes

and his suggestion that the Garo-Rajmahal Gap appeared later than Miocene times to explain it were interesting to plant geographers as well.

It is well known that the Malayan Archipelago element is the predominant element in the flora of the perennially humid regions of India, *e.g.* the Upper Assam Valley, the Khasi Hills, the forests at the foot of the Himalayas from the Brahmaputra to Nepal, the Malabar Coast and Ceylon. While the Assam Hills and the Himalayas may be considered as almost continuous with the Malayan and Burmese hills, there is no direct land connection between them and the Malabar Coast and Ceylon. Direct migration across the seas being ruled out owing to the distance, other possibilities have to be taken into account. It is suggested, for example, that the Indian climate was very much more humid in the past, and therefore could allow migration of these types along the tops of the comparatively low hills in the Peninsula. One has, however, still to explain migration across the large gap between the Garo and Rajmahal Hills, which is possible if Dr. Hora's suggestion proves to be correct.

Dr. W. D. West congratulated Dr. Hora on his interesting paper, and considered that the facts he had brought forward would have to be explained by the geologists, rather than that the zoological evidence should be used to try and confirm geological hypotheses. As regards the fossils found near Darjeeling, it appears that they were discovered by Mallet near Sivok. They were recently examined by Mr. F. E. Eames of the Burmah Oil Company, who had concluded that though it was not possible to determine their age, except to say that they were Tertiary, the rocks in which they occur were definitely deposited under freshwater conditions. Thus these fossils do not furnish evidence of any extension of the sea into that area at the time they were living.

As regards the Rajmahal-Garo Gap, the consensus of opinion seemed to be that it is an old feature, though until the emergence of the Shillong plateau it seems to have been a 'gap' with only one side, the west side.

It may also be pointed out that according to the Geodetic Branch of the Survey of India there is a line of excess gravity running along the Satpura trend towards the Shillong plateau. According to Brigadier E. A. Glennie 'the Gangetic trough does not extend below the delta into the Bay of Bengal. Though locally closed in the Jalpaiguri area the trough recommences further east and then almost certainly bends south following the curve of the Arakan Yoma Range and of the Andaman and Nicobar Islands'.[1] It is still uncertain what conclusions can be drawn from this geodetic work as applied to geology, because these features are probably deep-seated, and moreover the geodesist can give us no indication as to the age of their formation. Nevertheless, it is probably worth while drawing attention to them.

In reply, Dr. Hora thanked the speakers for their valuable suggestions and helpful criticism, and hoped that the data thus collected by their joint efforts might stimulate further research on the palaeophysiography of the region between the Assam and the Eastern Himalayas on the one hand and the ancient Satpura trend on the other. If it is shown by subsequent researches that the Garo-Rajmahal Gap is a fairly ancient feature of this part of India, and that possibly a zone of highland extended between the Monghyr and Rajmahal Hills on the south and the Darjeeling and Eastern Nepal Himalayas on the north, the discontinuous distribution of the fishes referred to above could even then be readily understood.

From his intimate knowledge of the ecology and bionomics of Indian torrential fishes, Dr. Hora assured Capt. Thomas that there was no possibility of the fish eggs or larvae being transported through sluggish and muddy waters on to rocky areas or through the agency of birds. Moreover, the distance between the extreme south of India and the Assam and Eastern Himalayas was so great that such migration did not seem possible.

As regards meteorological means, such as violent cyclonic storms, causing 'rains of fishes', it could be stated that so long as the distribution of land and sea remained as at present, there could be no chance of cyclones carrying fish from Assam to the Western Ghats. As there was every reason to believe that there had been no change in the water and land areas since the origin of the fish fauna dealt with here, this possibility of dispersal need not be given any serious consideration.

[1] Geodetic Report for 1937, p. 27 and Chart IX (1938).

# AGE OF TRANSGRESSION OF THE BAY OF BENGAL AND ITS SIGNIFICANCE IN THE EVOLUTION OF THE FRESHWATER FISH FAUNA OF INDIA

BY

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*Reprinted from Bulletin No. VII : Symposium on Organic Evolution*

NATIONAL INSTITUTE OF SCIENCES OF INDIA

NEW DELHI

✓AGE OF TRANSGRESSION OF THE BAY OF BENGAL AND ITS SIGNIFICANCE IN THE EVOLUTION OF THE FRESH-WATER FISH FAUNA OF INDIA*

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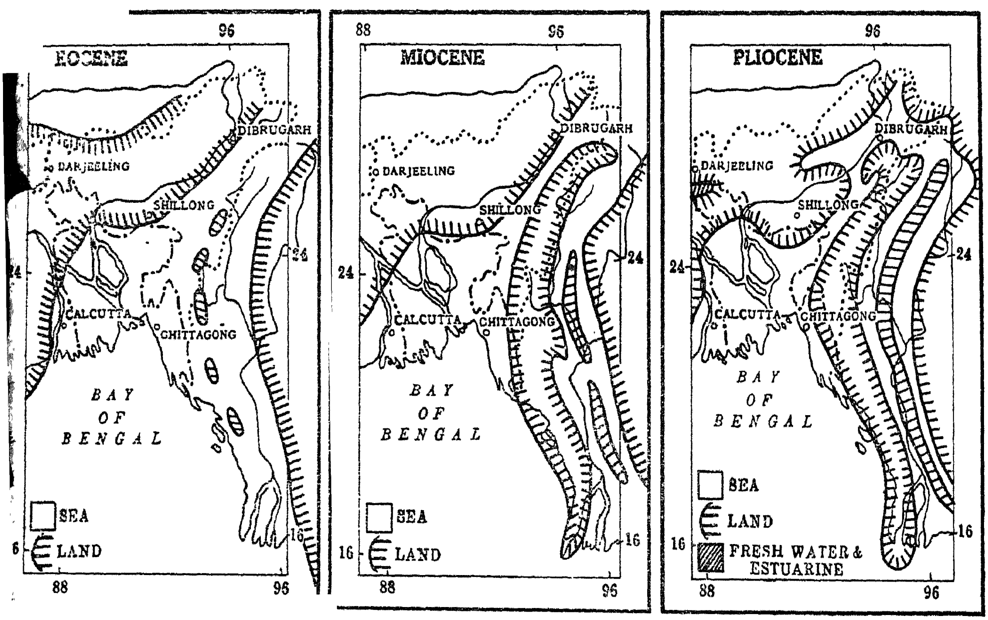
(Communicated by S. L. Hora, F.N.I.)

[ SUMMARY ]

Fossil records of freshwater fishes show that from the Triass to the early part of the Eocene there were several waves of migration of freshwater fishes (Dipnoans, Ganoids, Osteoglossids and Teleosts) from the mainland of Asia over the Assam region to Peninsular India. There are no freshwater Indian fish fossils of the late Eocene or the Miocene Periods, but fossils of the early Pliocene and later periods are then found in the Siwalik and the Karewa Beds of the Himalayas. The recent find of a marine Ganoid fish from the Garo Hills, Assam, has enabled the author to fix the probable age of the transgression of the Bay of Bengal which cut off the land route of migration of these fishes. The evolution of the freshwater fish fauna of India in terms of the above-mentioned palaeogeographical changes is discussed.

INTRODUCTION

In two recent communications (Hora and Menon, 1952, 1953) dealing with the distribution of Indian fishes of the past, it has been pointed out that during the Mesozoic period there existed a land bridge in the Assam region, across the ancient east-southward extension of the Tethys Sea, connecting Peninsular India and the northern land mass ; and that our earliest freshwater fishes, like the Dip-




1. Map of north-eastern India showing the northward transgression of the Bay of Bengal during the Eocene, Miocene and Pliocene periods. *After* Krishnan (*Bull. Nat. Inst. Sci. India*, 1, 26-28, 1952.

* Published by the kind permission of the Director, Zoological Survey of India.

noans, the Ganoids, the Osteoglossids and a few Teleosts, had crossed over to India along this land route. It was also pointed out that this land bridge had probably existed up to the Eocene, when the transgression of the Bay of Bengal had occurred, thus cutting off the land route of migration of fishes until the Pliocene, when it was once again established. Subsequently, the discovery of a marine Ganoid fish from the Garò Hills, Assam (Menon and Prasad, 1953) has enabled the authors to fix the probable age of the transgression of the Bay of Bengal as Middle Eocene. In the light of this recent knowledge of the palaeogeography of the north-eastern part of India, the evolution and spread of the Indian freshwater fish fauna are discussed in this paper.

## Freshwater Fish Genera of India

There are altogether 89 genera of primary (Myers, 1938) freshwater fishes, which can be arranged into the following 12 groups according to their zoogeographical relationships :

### *Group I*

The 13 genera listed below are found in the Far East as far as South China, the Malay Archipelago, India and westward as far as Africa *via* Afghanistan, Persia and Syria or Arabia.

1. *Notopterus* Lacépède
2. *Barilius* Hamilton
3. *Garra* Hamilton
4. *Rasbora* Bleeker
5. *Puntius* Hamilton
6. *Labeo* Cuvier
7. *Nemachilus* van Hasselt
8. *Tor* Gray
9. †*Channa* Scopoli
10. †*Clarias* Scopoli
11. †*Anabas* Cuvier
12. *Ambassis* Cuvier & Valenciennes
13. *Mastacembelus* Scopoli

### *Group II*

The following genera are found in the Far East as far as South China, the Malay Archipelago, India and westwards only as far as Afghanistan, Persia or Syria :

1. *Cirrhina* Oken
2. *_Oreinus_ McClell.
3. *_Schizothorax_ Heckel
4. *Glyptothorax* Blyth
5. *Mystus* Scopoli
6. *_Silurus_ Linnaeus

### *Group III*

Group III consists of genera widely distributed in the Far East as far as South China, the Malay Archipelago and India. They are entirely absent from countries west of India.

1. *Chela* Hamilton
2. *Laubuca* Bleeker
3. *Esomus* Swainson
4. *Danio* Hamilton
5. *Aspidoparia* Heckel
6. *Amblypharyngodon* Bleeker
7. *Crossocheilus* Van Hasselt
8. *Catla* Cuvier
9. *Lepidocephalichthys* Bleeker
10. *Botia* Gray
11. *Wallago* Bleeker
12. *Ompok* Lacépède
13. *Rita* Bleeker
14. *Clupisoma* Swainson
15. *Bagarius* Bleeker
16. *Eutropiichthys* Bleeker
17. *Heteropneustes* Muller
18. *Badis* Bleeker
19. *Nandus* Cuvier & Valenciennes
20. *Colisa* Cuvier & Valenciennes

†*Channa*, *Anabas* and *Clarias* are also known from Japan, but they seem to have been introduced there by man (Myers, 1951; Okada & Nakamura, 1953).
*These are also found in the Trans-Himalayan region.

*Group IV*

The following genera are known as far as Siam or South China and along the base of the Himalayas on the one hand and the Peninsula on the other :

1. *Osteobrama* Heckel
2. *Gagata* Bleeker
3. *Amblyceps* Blyth
4. †*Psilorhynchus* McClelland

*Group V*

The following 5 genera are found as far east as Burma, Siam, South China or the Malay Archipelago and the Eastern Himalayas on the one hand and Peninsular India on the other :

1. *Acrossocheilus* Oshima
2. *Laguvia* Hora
3. *Batasio* Blyth
4. *Pangasius* Cuvier & Valenciennes
5. *Pseudeutropius* Bleeker

*Group VI*

Genera belonging to this group are known from Burma, Siam, South China or the Malay Archipelago on the one hand and Peninsular India on the other :

1. *Oreichthys* Smith
2. *Osteochilus* Gunther
3 *Rohtee* Sykes
4. *Schismatorhynchus* Bleeker
5. *Thynnichthys* Bleeker
6. *Homaloptera* Van Hasselt
7. *Macropodus* Lacépède
8. *Pristolepis* Jerdon

*Group VII*

This group consists of a single genus which is widely distributed along the Himalayas from the Brahmaputra drainage system to the Indus system and is also found in the Peninsula.

1. **Sisor* Hamilton.

*Group VIII*

This group consists of genera found in the Eastern Himalayas on the one hand and Peninsular India on the other.

1. *Balitora* Gray
2. *Erethistoides* Hora
3. *Hara* Blyth
4. *Proeutropiichthys* Hora
5. *Silonia* Swainson
6. *Amphipnous* Müller

*Group IX*

The following genera are restricted to the Eastern Himalayas and the Far East :

1. *Semiplotus* Bleeker
2. *Acanthophthalmus* Van Hasselt
3. *Euchiloglanis* Regan
4. *Exostoma* Blyth
5. *Pseudecheneis* Blyth
6. *Chaca* Cuvier & Valenciennes
7. *Olyra* McClelland
8. *Fluta* Bloch

†*Psilorhynchus* McClelland has not so far been recorded to the east and south of Burma.

*Recently discovered in the Son river drainage, Vindhya mountains, by the officers of the Central Inland Fisheries Research Station, Barrackpore.

*Group X*

This group consists of genera endemic to the Eastern Himalayas.

1. *Aborichthys* Chaudhuri
2. *Somileptes* Swainson
3. *Conta* Hora
4. *Erethistes* Müller & Troschel
5. *Myersglanis* Hora & Silas
6. **Ctenops* McClelland

*Group XI*

The following genera belonging to this group are endemic to Peninsular India :

1. *Parasilorhynchus* Hora
2. *Bhavania* Hora
3. *Travancoria* Hora
4. *Lepidopygopsis* Raj
5. *Jerdonia* Day
6. *Nemachilichthys* Day
7. *Horaglanis* Menon
*Horabagrus* Jayaram
9. *Neotropius* Kulkarni

*Group XII*

This group consists of 2 genera Widely distributed in Northern India.

1. *Ailia* Gray
2. *Rhynchobdella* Bloch & Schneider

*Group XIII*

Under this group comes the solitary Western genus whose range extends as far 'as the West Punjab.

1. *Scaphiodon* Heckel

From the above analysis, it is abundantly clear that the freshwater fish fauna of India has a very close Malayan affinity (Hora, 1944) and that there is hardly any Ethiopian element in it. It is remarkable to note that there is not a single genus common to India and Africa, which is also not found in the Malayan region. On the other hand, it is the Indian element that is present in the fauna of Africa. Taking the first group of 13 genera, *Garra*, *Puntius*, *Tor*, *Nemachilus*, *Clarias* and *Mastacembelus* are found either in Afghanistan, Persia and Arabia or Syria in addition to Africa, India and Farther East. The occurrence of these forms in countries between India and Africa is very significant, as it suggests the probable route of dispersal of these forms to Africa. In the case of Clariid fishes it has been shown (Menon, 1951) that the route of dispersal was along Afghanistan, Persia and Syria. Group II indicates the same route of dispersal westwards of the South-East Asian forms. Group III establishes the great affinity between the Indian and the Malayan forms. Groups IV, V, VI, VII & VIII are of special significance as they establish not only a close affinity of Indian fauna with that of the Far East, but

*The Indian species generally referred to as *Osphronemus nobilis* (Day, *Zool. Record*, 1869, p. 133) should bear the name *Ctenops nobilis* (McClelland, *Calcutta Journ. Nat. Hist.*, 1845, p.282). *Osphronemus* Lacépède, with *O. goramy* as the type, is known from S. China, Java, Borneo, Sumatra and other East Indian islands, but it has also been introduced into India and is now thriving well in the Peninsula. *Osphronemus* has, therefore, not been taken into consideration for the purpose of the discussion in this paper. *Etroplus* C. V. is another genus which has been transported to India by some means not understood at present. *Etroplus* is confined to Peninsular India and Ceylon and has its nearest ally in *Pareutroplus* Bleeker found in Madagascar. It is very likely that *Etroplus* came to India *via* the sea (Hora, 1937). Since "other African Chromides (Cichlidae) have acclimatized themselves at the present day in saline water, we think it more probable that *Etroplus* should have found its way to India through the ocean than over the connecting land area; where, besides, it does not occur". (Günther, 1880.)

they also indicate a direct spread of the South-East Asian and the Eastern Himalayan fauna to Peninsular India, probably during geologically recent times. Group IX indicates a predominence of the Malayan element in the Eastern Himalayas. Groups X and XI consist of genera endemic to the Eastern Himalayas and Peninsular India respectively. Groups XII and XIII are not of much significance for the discussion of the zoogeographical relationships of the fish fauna of India, as the former consists of genera widely distributed in Northern India and the latter represents the solitary Western genus in the freshwater fish fauna of India.

## Pre-transgression Elements in the Freshwater Fish Fauna of India

The Dipnoans (*Ceratodus* Ag.), the Ganoids (*Lepidotus* Ag., *Dapedius* Leach, *Tetragonolepis* Brown, *Pycnodus* Ag. and *Lepidosteus* Lacépède), the Osteoglossidae (*Musperia* Sanders), the Acanthopterygian fishes (*Anabas* Cuvier, *Polycanthus* C. V., *Nandus* C. V. and *Pristolepis* Jerdon), and probably a Cyprinoid genus doubtfully recorded as an Abramid fish (Hora, 1938, p. 274), constitute the pre-transgression element in the extinct freshwater fish fauna of India. Of these, Dipnoans seem to be the earliest freshwater fishes that reached India as is evidenced by the fossil genus *Ceratodus* in the Maleri Beds of the Godavari Valley of the Upper Triassic Period, approximately 170 million years old. There were three waves of Ganoid migrations to India. The first wave consisted of *Lepidotus*, *Tetragonolepis* and *Dapedius*, but they were soon exterminated by the desiccation that followed. A second wave of migration during the Upper Cretaceous consisted of the genera *Pycnodus* and *Lepidosteus* which were soon entombed in the first flow of the lava series which formed the first layer of the Deccan Traps. A third wave of migration of Ganoid fishes, along with some of the modern fishes, took place during the early Eocene, but these were also exterminated by the subsequent lava flows (*vide* Hora & Menon *loc. cit.*, p. 35).

Like the Dipnoans and the Ganoids, the Osteoglossid genus *Musperia* spread to India during the early Eocene along the same route as the earlier fishes.

*Anabas*, *Polycanthus*, *Nandus* and *Pristolepis* are the Acanthopterygian fishes of the pre-transgression period in India. *Nandus* and *Pristolepis*, belonging to the family Nandidae, are to-day distributed over the whole of south-east Asia, but a closely allied form *Polycentropsis* represents them in Africa and South America. *Anabas*, belonging to the family Anabantidae, seems to have originated at a somewhat later period for they did not extend to South America, probably because the land connection between Africa and South America was completely severed by the time it reached Africa.

During the pre-transgression period no Ostariophysi had migrated to India, except probably the doubtfully recorded primitive carp of the subfamily Abramidinae (Hora, *op. cit.*). It is, however, evident from the fossil records that the Ostariophysi had spread from Europe during the early Tertiaries, but not southwestwards to India (*vide* Hora and Menon, *loc. cit.*, p. 109).

## Post-transgression Elements in the Freshwater Fish Fauna of India

With the transgression of the Bay of Bengal in the Middle Eocene and the submergence of the land connection between the Peninsula and the rest of Asia, the migration of the freshwater fish fauna to India was cut off for some time, *i.e.*, from the Middle Eocene to early Pliocene. The dispersal of the fauna from the North-East to India was, however, again made possible with the major upheaval of the Himalayas, which seems to have occurred towards the close of the Miocene or early Pliocene. This had probably rendered the

arm of the sea shallow and had cut it up into shallow lagoons and freshwater lakes. Gradually, with the further rise of the Himalayas, the shallow area may have become a marshy land enabling the marsh-loving fishes to cross over to India. The Siwalik fossil deposits of *Clarias* Scopoli, *Heterobranchus* Geoffroy, *Channa* Scopoli (*Ophiocephalus* Bloch), *Chrysichthys* Bleeker, *Mystus* Scopoli, *Rita* Bleeker, *Bagarius* Bleeker and *Silurus* Linnaeus (Hora and Menon, *loc. cit.*, p. 106) provide ample testimony for the migration of freshwater fishes to India during the Pliocene period. During the early post-transgression period, *i.e.*, during the Pliocene, the area occupied by the present-day Garo-Rajmahal hills was still under the sea and the route of migration of freshwater fishes was entirely along the base of the young Himalayas. The absence of any fossil fish of the Miocene to Pliocene periods in the Peninsula indicates that the migration southwards had not taken place then.

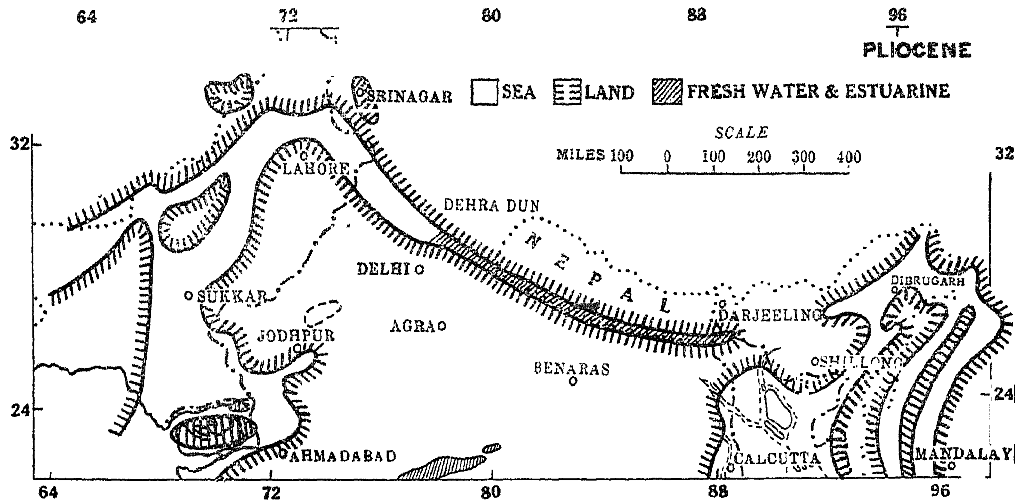
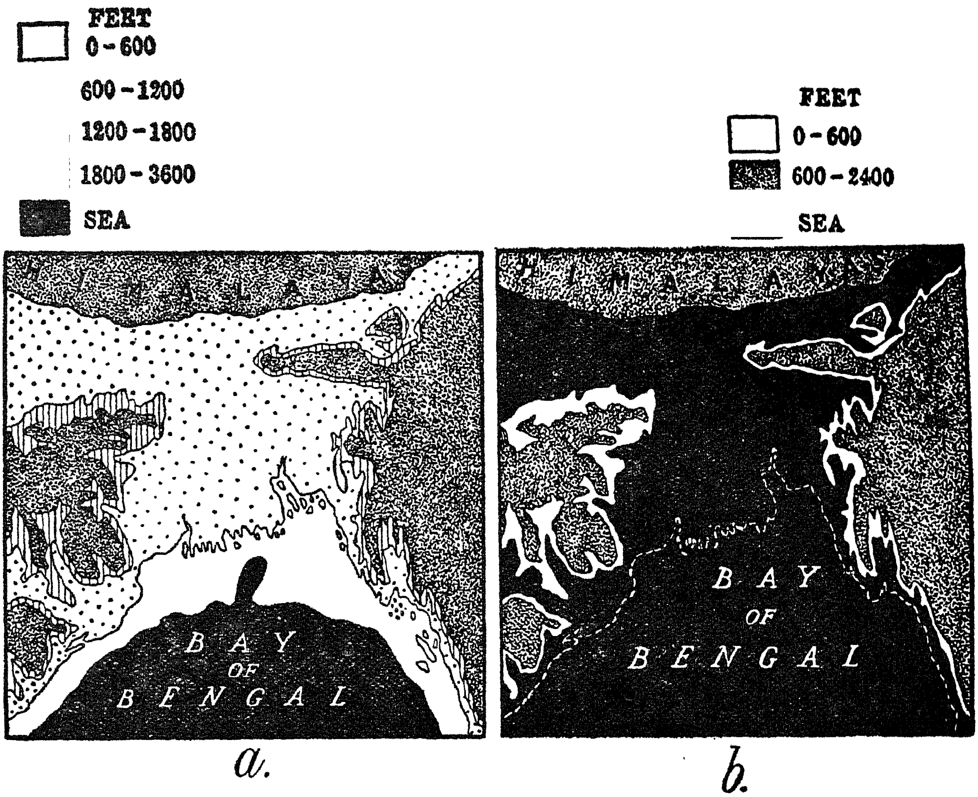



Fig. 2. The Siwalik foredeep of the Pliocene period. *After* Krishnan (*Ibid.*, p. 28).

The invasion to India of marsh-loving fishes like *Clarias* and *Channa* (*Ophiocephalus*) seems to have occurred first. With the gradual replacement of the marshy condition, and the establishment of drier lands with pools and ditches, in the area between India and China as the Himalayan upheaval proceeded further, forms like *Mystus* and *Rita* crossed over to India. With a still further upheaval of the Himalayas, the low east-westward hills of the young Himalayas seem to have made their appearance in the region between India and China, which enabled the migration of fishes of clear water streams, like *Bagarius* and *Silurus* during the late Pliocene period (*vide* Hora, 1953).

Most of the present-day fish fauna of India, however, is descended from the Pleistocene migrants. While the migration along the Himalayas westwards commenced in the Pliocene and continued uninterrupted probably till the late Pleistecene, when the dismemberment of the westward flowing drainage at the foot of the Himalayas had occurred (Hora, *loc. cit.*, p. 10), the migration southwards to the Peninsula had taken place entirely during the Pleistocene and intermittently in several

waves.* We have already noticed that, when the migration along the Himalayas commenced during the Pliocene, the area between the Garo-Rajmahal gap was still under the sea and did not permit the south-westward migration. Only with the lowering of the sea level during the pluvial period of the Glacial Age, does the Garo-Rajmahal gap seem to have become a plateau facilitating the movement of hill-stream and other freshwater fishes south-westwards (Hora, 1951). During the arid




Eig. 3. Orographic features of the Garo-Rajmahal gap. *a*. Condition during a glacial period *b*. Condition during an interglacial period. *After* Hora (*Proc. Nat. Inst. Sci.*, 17, 1951)

phases of the Pleistocene, with the rise in the sea level, the Garo-Rajmahal gap seems to have become submerged under the sea, thus preventing the migration of the fauna to the south. Thus, there were five waves of migration of fishes over the Garo-Rajmahal gap to the Peninsula corresponding to the five Glacial periods of the Pleistocene, the pluvial periods facilitating the migration and the arid periods isolating them and thereby inducing rapid speciation in the Peninsula. In the Peninsula, endemicity and the degree of divergence is most pronounced in the southernmost portion of the Western Ghats, due to the long isolation of the Malayan forms there and decreases as one goes up along the Ghats until it becomes negligible in the Vindhya Satpura portion as the forms that colonize the waters

* It is perhaps necessary to point out here that the river Ganges in its present form came into existence only during the very late Pleistocene, probably just before the last glacial period, and therefore could not have acted as a barrier to the dispersal of torrential fishes. During the last glacial period, the deltaic fauna of the Ganges and the Mahanadi probably commingled over the newly exposed land (Hora, 1951).

to-day are of the later waves of migration. For a detailed account of the dates of the waves of migration of the Malayan fish fauna to the Peninsula and their evolutionary divergences, reference is invited to Silas (1952). While the members of the Malayan fauna isolated on the Indian Peninsula indicate various levels of evolutionary divergences, the Himalayan fish fauna does not show such divergences from the Malayan forms, except probably in the Eastern Himalayas, where the recent orogenic movements (Chibber, 1949) have brought about a certain amount of speciation. A detailed account of the fish fauna of the Himalayas will soon be published by the author elsewhere.

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# JOURNAL

OF THE

# MYSORE UNIVERSITY

SECTION B

CONTRIBUTION 12 IN GEOLOGY


# SOME ASPECTS OF THE DECCAN TRAPS—A REVIEW


BY

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Vol. X, PART IV, pp. 25 to 39

[ *Published April 20, 1950* ]

PRINTED AT THE BANGALORE PRESS, MYSORE ROAD

BANGALORE CITY

1950

# SOME ASPECTS OF THE DECCAN TRAPS—A REVIEW

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Received January 12, 1950

EVER since Prof. Birbal Sahni reopened the question of the age of the Deccan Traps in the year 1934[7] our interest in this formation has been actively revived and several papers have been published dealing with this and other allied problems connected with these lava flows. The object of the present paper is to review this recent work, with particular reference to two important aspects of the Deccan Trap formation—(*i*) the nature and disposition of the 'feeding fissures' for these eruptions, and (*ii*) the age of this eruptive activity. These two aspects are, in a way, closely interrelated and are best considered together.

## 'FEEDING FISSURES' OF THE DECCAN TRAPS

From the days of W. T. Blanford who established, nearly 80 years ago, that the Deccan Traps are the result of the accumulation of subærial lava flows, geologists have tried to ascertain the nature and recognise the location of the numerous fissures through which such enormous quantities of lava have been erupted. In the earlier days, the fact that a number of dykes were noticed here and there in the Deccan trap country, as for instance in the Rajpipla hills, in Cutch, Kathiawar, and other parts of Western India, seemed to furnish an answer to this question; for they would obviously indicate the required 'passages'. But in the light of what we now know regarding the duration and history of these eruptions, it is realised that the problem is not so simple. On the other hand, the perusal of the recent paper on " Dykes in Western India—a Discussion of their relationships with the Deccan Traps " by Dr. J. B. Auden[1] shows how difficult this problem is. In this important paper, Auden has given a detailed account of the numerous dykes occurring in the different parts of the Deccan Trap area and points out that " these are not distributed in a haphazard manner, but are concentrated as clusters, swarms, arcuate dykes, and dyke networks in definite areas." A significant fact regarding these dyke swarms and networks is that "large areas of the lavas appear to be free from dykes; for the dykes, where they occur in abundance seem to be concentrated in well-defined zones next to which are much wider areas where the dykes are scarce or absent". From an elaborate study of the nature and disposition of these dykes, evidences have also been

provided in this paper which indicate "that many of these dykes were possibly altogether later than the lavas into which they are injected and may have belonged to a subsequent hypabyssal phase". In the concluding part of the paper, Auden refers to the views put forward by Glennie on the basis of gravity observations which indicate that "the Deccan Traps have little systematic influence on the gravity anomalies; and the high positive anomalies are to a large extent independent of surface geology, and indicate warps in the basalt and dunite layers of the sima. The distribution of dyke swarms in Western India may well be concentrated in the region of sub-crustal warps...... The actual *manner of extrusion* of the lavas cannot however be determined by geodetic evidence, the value of which is in the indication of a raised basaltic layer and the thinning of the sial crust." Now that it is clear that many of the dykes in the Deccan Traps were intruded later than the outpourings of the lavas, "the problem becomes the more urgent as to the manner of the eruption. of the lavas."

In this search for the 'feeding dykes' of these eruptions special importance is attached to the recognition of the first fissures which were ripped open in the pre-trappean terrain and served as channels for the earliest lava flows This is indeed a very interesting problem and is closely connected with the question of determining which the earliest flows are in the present mass of the Deccan Traps,—a point of vital importance also in determining the age of these first eruptions. The problem of these 'first fissures' has also been ably discussed in all its aspects by Auden in his recent paper.

Following the well accepted idea that the first eruptions took place along the eastern margin of the Deccan Trap area and remembering that what we now see of the Deccan Traps is only a remnant of the original formation after a long period of subaerial denudation, one would naturally look for the first 'feeder dykes' in the belt of country just outside the present eastern margin of the trap area. The question also arises here whether the small but important outliers of the Deccan Trap in Rajahmundry and in Sind originally formed part of the main body and have now been separated due to the denudation and removal of the traps in the intervening country, or whether these were distinct and separate from the beginning; our view on this point will influence our outlook in the search for the 'feeder dykes' in the intervening areas.

In this connection attention may be drawn to the ideas put forward by the present writer in a comprehensive paper on "The Deccan Traps" published in 1936.[6] In this paper, the problem of the exact nature and behaviour of the floor on which the lava flows accumulated and the location of the first feeding

fissures on the pre-trappean surface have been discussed. The picture visualised therein regarding the evolution of the geological history of the trappean area and the distribution of the lava flows of successive periods of eruptive activity, will be helpful not only in dealing with the question of the 'feeding fissures' of the Deccan Trap flows, but also in discussing the problem of the age limits of these eruptions. Special attention may here be drawn to the following extracts from this paper. "The Deccan Trap eruptions of lava (immediately after the final close of the trappean period) covered not only a large part of peninsular India but must also have extended over quite a large area of this land to the southwest of the present coastline. This extensive area of eruptive activity appears to have been generally in the form of a broad, shallow (probably saucer-like) depression more or less oval in outline with its longer axis roughly NE-SW. Of course the sides and bottom of this depressed area were not so smooth and regular as in the case of the analogy suggested, but were highly irregular being composed of a number of more or less gently undulating ups and downs, with several lines of drainage determined by the irregularities of denudation necessarily present on such an ancient land area; and it is presumed that the fissures were split open on the floor of such a basin."....(*i*) " Under these circumstances, with the continual emission of highly fluid lava, almost as thin as water according to Iddings, from these fissures the lavas will flow out, fill up all the minor depressions and thus ultimately tend to fill the entire basin from below upwards covering all the irregularities in this process; and with the lavas highly fluid and mobile, they would naturally at all stages of this filling up show a more or less level surface. Further, when the basin is thus filled up by the consolidated lava, the main vents themselves through which the lavas came out would be covered up by the entire thickness of the lava flows above, thus concealing them from view altogether. Thus though fed only by a few vents on the floor of the basin, the highly liquid lavas would gradually extend out and cover more and more of the outer regions of the basin till atlast the entire basin is filled up and the area becomes more or less a flat plain of lava. It would thus be possible to see along the peripheral regions, for instance, of such an area quite a thick series of lava flows, without any actual vent being noticeable below." These first lava flows are what we now recognise as the 'lower' traps. Then there was a pause. (*ii*) "Sometime later, there was a violent recrudescence of eruptive activity, and new fissures were opened out from time to time through which enormous volumes of lava were extravasated. But now there appears to have been a gradual diminution in the eruptive area, the general tendency being for the concentration of the eruptive fissures in the central part of the original basin, in the country within a radius

of about 100-150 miles from Bombay. Side by side with this, as a consequence of the diastrophism which ultimately brought about the foundering of this part of the Gondwanaland southwest of Bombay, there appears to have arisen a gradual and gentle 'sagging' or 'warping' of the ground which became more and more pronounced as we approached the centre of the new area of eruptive activity. Thus there would come about in this region a fairly pronounced depression, gradually shallowing away as we went outwards and finally merging into the flat country of the lower traps all round. The lava flows succeeding the lower traps were more or less confined to this depressed area, the floor of which appears to have further subsided gradually in course of time under the weight of the increasing lava flows above. The diastrophism in this area accompanied by the voluminous extrusion of the underlying basaltic magma must have disturbed the isostatic equilibrium, so that locally the crust began to yield and sag under the increasing load above—a load composed of basaltic lava which is much heavier than normal sediments. Thus arose conditions favourable for the accumulation of enormous thicknesses of lava reaching a maximum of about 5,000 feet or more in the central part of the area, the different flows making up this thickness being under these conditions always more or less horizontal. These constitute what we now call the 'middle' traps. This second eruptive activity was much more powerful than the first and very much larger volumes of lava were extravasated. These eruptions were obviously so continuous both in time and space that no inter-trappean sedimentary beds could be formed.".........(*iii*) " Sometime after the formation of the middle traps, there was again a recurrence of eruptive activity, but now confined to an area even smaller than that of the second series of eruptions—just within a radius of a few miles round about Bombay. These lava flows the 'upper' traps of the present-day represent the last stages in the decline of volcanic activity and were feeble and intermittent. These lavas, like the later flows of the middle trap period, had to come out through fissures cutting through a great thickness of the traps below, and were therefore naturally accompanied by the formation of ash beds.".....
(*iv*) " Not long after the close of the upper trappean period, there came about the foundering of the land bridge between India and Madagascar, and with it went down a part of this great trap formation below the sea. The western coastline of India was now established practically in its present configuration.

The four progressive stages numbered above roughly correspond to the four main periods of eruptive activity comprised within the general term 'The Deccan Traps', and each with its own set of associated 'feeding fissures'. It is significant to note that the hypothesis suggested above of a sinking floor

during the progress of volcanic activity is also confirmed by Auden who says: "Since borings prove that the base of the traps now extends in many localities to considerable depths below the sea level, there are confirmatory indication of inter-trappean or post-trappean depression of the pre-trap floor."

On the question of the former extension of the area of these trap flows beyond the present western coastline, the results of the recent studies of the floor of the Arabian Sea by Wiseman and Sewell[10] are interesting. They were able to obtain fragments of rock from the sea bottom both on the Carlsberg ridge, and from the deep basin on its north-eastern side. All of these were of the basaltic type. In their chemical composition, however, these basalts seem to differ in some respects (*e.g.*, in showing less total iron) from the average composition of the Deccan Trap in India. But from what we know of the variations in the chemical composition of the Deccan basalts among themselves in India, it may not follow that " these basalts from the Indian Ocean cannot be regarded as a westward continuation of the Deccan Trap". As the authors themselves have stated "since geophysicists regard the earth as showing a gradual increase in iron from the periphery to the core, the question may be asked whether it is possible for continental basalts which presumably have been thrust to the surface through a greater thickness of sial to originate at greater depths and consequently be richer in iron than those erupted on the ocean floor". It may be noted, however, that this statement implies that these basalts recently collected from the Indian Ocean were erupted '*on the ocean floor*'; but whether it was so, or whether it is not a case where these lavas were erupted on land areas and these have since been submerged and become part of the ocean floor, is a point for consideration.

In this connection, reference may be made to the views expressed on some of these questions by Prof. N. Krebs, the well-known German geomorphologist, in a paper which he published in 1933[4] based on observations made during a visit to India in 1931. I have not been able to refer to this paper in original; but a nice summary of Krebs's morphological observations in relation to the views expressed by me in the 1936 paper[6] has been given by Dr. Arthur Geddes (of the Department of Geography, University of Edinburgh) in a personal communication on " Recent theories of the structure, erosion, and relief of the Deccan Traps—a Review" which he prepared and sent me after his visit to these parts in 1939, and based on his own observations, field notes, sketches and photographs both on land and from the air. As Geddes puts it, "this morphological approach is the more valuable in that the structural data are meagre, both because of the difficulty of stratigraphy in lavas such as these, and because of the drowning of the westernmost

outflows by the sea." Referring to the present disposition of the lavas along the coast in the neighbourhood of Bombay, Geddes says: "From the summits of the Ghats around Bombay, there is a definite dip of the strata westwards towards the sea (though hardly observable to the naked eye) as well as a more marked and clearly visible dip towards the structural basin of Bombay which is noticeable as one enters the harbour. This dip of the strata shows that the last phase in the great series of continent building disturbances was the downwarping into the Arabian Sea of these lava beds and of the underlying crust, with or without faulting in addition. One is even inclined to ask, with Krebs, whether this final phase of warping may not have been accompanied by the creation of fresh fissures and lava outflows witnessed to by the roughly north-south direction of so many of the minor ridges and valleys of the Konkan lowland. It should be added that this subsidence of the western portion of the Gondwana continent westwards of the present Konkan coast may well have been accompanied by a slight uplift, or upward warping at the time. This would help to explain that while the strata dip seaward to the west of Matheran,—an isolated north-south ridge which continues the axis of the western ghats northwards into the Bombay embayment,—to the east of this ridge, there is an appreciable dip the other way. Hence the present altitude of the western ghats relatively to the west of the Deccan Trap summits, would be augmented by slight uplift, concurrent with profound subsidence forming the Arabian Sea. It is worth examining the evidence for this assumption in greater detail by comparing structural data established by earlier geological survey with Krebs's comments on the associated morphology." Talking of the tectonic trend lines and associated structural features as shown by physiographical studies, Geddes says: " The revelation of the structure lines by the dominant north-south ridges and valleys, and secondarily by other NW-SE or W-E trends have been ascribed to the resistence of harder magma which had welled through fissures; but it may be that secondary heating of the pre-existent lavas hardened these, so leaving these *in situ* after the intrusive matter had itself been eroded. Dykes there are however which go straight across the country forming the cores of ridges, whether as combs along mountain ranges, or as dark walls over the more level portions of the plateau. They are particularly noticeable in the neighbourhood of the Tapti and Narbada rivers in a west-east direction; and in the floor of the Tapti valley between 74° and 75° E, they form a ribbed floor to the valley which shows through the forest cover, cultivation being impossible on so rough a surface. Where found, most frequently they are of weathered columnar basalt. They guide the details of the topography, the stream lines, and the minor modelling, often in consonance with the major direction of ridge and valley....

While the zigzag formation or front of the scarp of the ghats is influenced by the many differently oriented tectonic lines, its forms are exogenic, that is essentially due to the action of erosion. In a localised study such as this, one can do no more than recall that underneath the lavas atleast as far north as the northern edge of the Bhima basin, structural trends deflect the rivers somewhat southwards from the main direction of the slope (from west to east) to the Bay of Bengal. These trend lines, when produced, seem to run parallel to the picturesque ridges of the granitic rocks and schists which traverse the Mysore plateau from north to south, or rather from NNW to SSE. Thus the present trend lines of the lavas must correspond to a considerable extent to the underlying structure continuing the history and revealing the nature of the older shatter-belts below.... Yet however ancient may be the origin of the tectonic lines visible in the rock structure or influencing its sculpture, the most recent of the intrusions may belong even to a later stage than is specifically suggested by Rao. As Krebs points out, the last downwarping to the sea observable in the strata of the Konkan may well have been accompanied by final outpouring of lava." After reviewing all the observations, Geddes concludes: "The data of structure, when re-examined along with those of erosional forces and the resulting of land forms, thus combine to show that slow western warping and submergence have taken place and still continue. The predominance of well-marked lines of river valley or ridge close and frequently parallel to the coast show that the main recent and contemporary axis of warping and submergence near the coast, and marked by it, is a phenomenon continuous with the structural processes whereby the latest lavas welled up through fissures to the surface of this zone. There is thus harmony between these data reviewed by Krebs and those marshalled by L. Rama Rao to show that the latest concentration of the lavas accompanied a subsidence of the underlying rocks towards Bombay."

From this brief review, it is obvious that this aspect of the Deccan Trap study regarding the 'dykes' and 'fissures' associated with these lava flows and their relation to the previously existing tectonic trend lines in the trappean area is a very complicated one, and it is still difficult to speak of conclusions with any convincing definiteness. In considering this problem it is important to remember that the Deccan Trap formation is not the result of just *one* outburst of eruptive activity. On the other hand, we have several evidences to show that it was the result of a series of eruptions spread out over a fairly long period of time. In the words of Iddings, "not one burst but repeated flows through long ages have built the plateau of the Deccan." In fact, we now recognise 4 such units of eruptive activity, and it is clear that associated with each one of these units both in time and space there must have

been corresponding 'feeding fissures'. We must therefore recognise different 'generations' as it were of these fissures and resolve the present dyke systems in the Deccan Trap country accordingly, correlating those of each generation with the corresponding period of outflows. At the same time we must also remember, as Auden has shown in his paper, that not all dykes that we see now were necessarily of the nature of 'feeding fissures' for lava flows; some of them were mere intrusive masses which never opened out on the surface and must therefore be considered as 'non-feeder' dykes. Evidently more work is required in this fascinating study before an adequate solution of the dyke problem can be reached; Auden has actually indicated in the concluding part of his paper the several points in regard to which further data are necessary. In view of the difficulties in the stratigraphical correlation on field evidences of these lava flows in widely separated areas, and the recognition of the relative age of any given flows in any particular area in terms of the formation as a whole, it would be most helpful if some method is devised by means of which such an equivalence could be recognised, and we are able to decide to which part of the entire succession any given trap flow belongs. In the absence of fossils, this problem will have to be tackled from the petrological and petro-chemical side. If a sufficiently large number of selected samples from different stratigraphical levels recognised in the field could be examined in detail from the chemical and optico-mineralogical points of view, and possible variations plotted in a continuous series, it may be possible to construct a time scale,—any sample of the trap from any part of the formation being referable to its position in this scale using its specific chemical and mineralogical characters as an 'index' of relative age, much as a fossil would be in the case of fossiliferous strata. Another possible way of attacking this problem is perhaps from the side of 'radioactive' determinations. If a large number of determinations are made covering the full range of the trap samples from the lowest to the highest portions of the trap formation, then it may be possible to fix the relative age of any given trap flow in relation to the entire succession on this basis. Studies on the above lines may be expected to be very helpful in discussing many of the problems connected with the Deccan Traps. It is hoped that the ideas summarised and reviewed above will, by helping us to take stock of the present position, stimulate further research and discussion ultimately leading to a full and satisfactory solution of these problems.

## The Age of the Deccan Traps

Indian geologists are familiar with the recent controversy regarding the age of this Deccan Trap eruptive activity. For quite a number of years

we believed on the evidences and arguments first put forward by W. T. Blanford so far back as 1880 that the Deccan Traps were upper Cretaceous in age—the eruptions having started at or about the cenomanian time and dying out during the danian. In the year 1934, Prof. Birbal Sahni re-opened this question[7] and pointed out that the direct evidence of the numerous plant fossils which he noticed in the inter-trappean beds in the Nagpur-Chhindwara area did not fit in with the current 'upper cretaceous' view, but on the other hand clearly indicated an eocene age; and seeing that in this area, we are actually dealing with the earliest eruptions which belong to the base of the series, Sahni naturally proceeded to conclude " that the Tertiary era had already dawned when the first lavas of the Deccan were poured out. " This conclusion in favour of an eocene age was also supported by the study of the infra and inter-trappean beds and their fossils in the Rajahmundry area.[5] It has been repeatedly suggested that the traps near Rajahmundry also belong to the Deccan trap formation and are equivalent to the base of the series, corresponding in age with the traps of the Nagpur-Chhindwara area. This view has been further supported by the recent work of E. Venkayya[9] who, from a detailed petrological study of these trap rocks, finds " a close similarity in chemical composition between the Deccan Traps of this region and those of Central Provinces, though they have been separated by a distance of more than 200 miles. This lends support to the view that the traps of the Rajahmundry are genetically connected with the main Deccan Trap outliers." There can thus be no doubt that the evidence in this area is quite pertinent to this question of the age of the Deccan Trap and must be considered as supporting Sahni's conclusion in favour of an eocene age. Thus the controversy arose—are the Deccan Traps Cretaceous or Tertiary ?

Our starting point for the present review will be the Discussion on "The Age of the Deccan Trap" held at Hyderabad during the Science Congress in the year 1937; for on that occasion our attention was focussed on this problem and authoritative expositions of the various points of view were given by the leading workers in this field. At the end of this discussion, a full report of which has been published, it was generally admitted, in the light of recent studies, that this eruptive activity was definitely a post-cretaceous phenomenon. In the light of the new palæontological evidences, the old geological arguments of Blanford in favour of a cretaceous age were critically reviewed and discussed in a paper on the Deccan Traps published by the present writer in 1936[6]; at the Hyderabad Discussion in 1937, they were similarly scrutinised by Dr. Crookshank of the Geological Survey of India; in the year 1938, further comments were made on Blanford's views by Dr. M. R. Sahni in the course of a discussion on "Discrepancies in the

chronological testimony of fossil plants and animals" at the Calcutta session of the Science Congress. A careful perusal of all this literature makes it clear that there is nothing in the field evidences to go against the conclusion based on the direct testimony of the inter-trappean fossils in favour of an eocene age; and in fact, this was really the first view put forward by the pioneer geologists of a century ago.

It must however be remembered that the evidences which have been put forward in support of the Tertiary age all come from the lowermost or basal lava flows; and therefore what we have now done is to fix the *lower* age limit of the Deccan Trap formation; the question still remains as to when the eruptive activity finally closed down, or in other words—what exactly is the *upper* age limit of this formation ?

In several of the papers dealing with the recent discussion referred to above on the age of the Deccan Trap, passing references have been made to this question, and the tendency seems to be to think that the last eruptions had ceased before the close of the eocene and thus to believe that the Deccan Trap eruptive activity was confined to within the limits of the eocene period. During the 1937 discussion, Prof. Sahni had an open mind on the matter; but in 1940[8] he was inclined to the view that "the chances are that the whole of this imposing thickness of thousands of feet of igneous rock was poured out within the relatively short interval of the eocene period. Quite possibly, this terrible drama of fire and thunder was only a brief episode of the very earliest part of the eocene." In the discussion at Hyderabad in 1937, Dr. Crookshank concluded by saying: "In my opinion the earliest Deccan Trap flows ushered in the eocene period in India. There is no reliable evidence as to how long the vulcanism lasted; but from the general resemblance of the fossils in the uppermost inter-trappean beds at Bombay to those in the Central Provinces, I think it probable that all the trap flows are eocene." On the basis of his petrographical, chemical, and 'radioactive' studies of a number of samples of the Deccan Traps from Cutch, Kathiawar, Gujarat, and the western coast of India up to 80 miles south of Bombay, Dr. V. S. Dubey recognised 4 divisions in the Deccan Trap series, including the later acid and ultra-basic members several of which he said indicate a middle tertiary age. Dr. W. D. West was of the view that "there could be little doubt now that the age of at least the greater part of the Deccan Trap must be assigned to the early tertiary; he was less confident about taking the upper limits as high as Dr. Dubey wished."

It must be remembered that this question of the upper age limit is closely connected with our ideas regarding the duration of these eruptions as gathered

from the geological history of the Deccan Trap period. So far back as 1867, W. T. Blanford expressed the view that "a large division, even of geological time, may very probably have elapsed during the accumulation of the Deccan Traps." He says: "The Nagpur inter-trappeans are associated with the lowest traps seen near Nagpur (which according to him were cenomanian in age) and the Bombay inter-trappeans with the highest seen near Bombay; and as both belong to one series, it is fair to conclude that the period of their formation differs by a very large proportion atleast of the time during which the traps accumulated." In the year 1932, when Blanford's view of the upper cretaceous age was still current, Prof. K. K. Mathur and P. R. J. Naidu, in a paper on "Volcanic activity of the coastal tracts of Bombay, Salsette and Bassein" observed: "A certain amount of time must be allowed subsequent to the gigantic vulcanicity of the Sahyadri Range for their denudation to the level of the coastal plain before the lavas of Malabar Hill, Kharodivadi and Nale Sopara Hill made their appearance. The early investigators have very rightly grouped this phase as the uppermost division of the Deccan Trap; but there is a possibility of an appreciable gap between the middle and the upper divisions, and it is by no means certain that the Cardita beaumonti beds of Sind fix the upper limit for the igneous activity of the Bombay coast. There is atleast a possibility that it may be of a much later date." In my paper published in 1936,[6] I referred to this question of the upper age limit of the traps, and put forward certain considerations and arguments in support of the view that these eruptions which started at the dawn of the Tertiary continued not only throughout the eocene but extended, though intermittently, even into later periods. Recent investigations by Dubey, Kalapesi, Sukheswala and others on the age determinations by radioactive studies of some of the latest members of the Deccan Trap series found along the west coast of India seem to clearly support this idea of a much younger age limit. In a recent paper, Dr. S. L. Hora refers to the zoogeographical distribution of the fish fauna of the western ghats and says[2]: "It would appear that the final phase of the Deccan Traps most probably occurred in more recent times than the Tertiary." From the evidence afforded by the torrential fishes, it seems most probable, according to Hora, that the age of the final eruptions of the Deccan Trap is "not older than the Quaternary period of the earth's history." From a study of the distribution of crocodiles and chelonians in Ceylon, India, Burma and Farther East[3] he comes to a similar conclusion and is inclined to connect these fissure eruptions with the rise of the Himalayas. He says: "Like the Himalayan movements and probably contemporaneous with them, the outbursts of lava also occurred at varying intervals.... The last lava outburst may be contemporaneous

with the formation of the Siwalik hills in the Pleistocene period, or may be even younger than that, as is evident from the distribution of the present-day forms." Auden in his recent paper[1] on the Dyke problem has also referred to this question and says: "It is probable that the Deccan volcanic episode may have existed throughout a much longer period of time than was formerly supposed, notwithstanding the believed uniformity of petrological type over most of the area with the exception of Kathiawar.... Available evidence indicates that the extrusion of the Deccan lavas was prolonged, and quite possibly intermittent, and periods of eruptive quiescence may have intervened during which marine transgressions took place in the west." In this connection it is significant to note that we have on the other side of the Arabian Sea, a similar 'Trap formation' in Abyssinia; and according to Dr. C. S. Fox "the oldest of the Abyssinian lavas is not older than upper cretaceous, and was possibly poured out in eocene times. The younger traps, judging by fossil wood from inter-trappean beds, is probably of miocene age."

Side by side with the idea of correlating the Deccan Trap eruptions with the different phases in the Himalayan upheaval, there is also the other view that these eruptions are to be connected with the disruption of the Gondwanaland; for instance, in 1930 Joly said: "It was at or near the close of the cretaceous and dawn of the eocene that this great continent (named by Suess Gondwanaland) broke up and as a continent disappeared. This event was, so far as we know, synchronous with the overwhelming of Peninsular India by a mile deep covering of the basaltic substratum. And further, it is believed that the diastrophism in Gondwanaland was connected with the movements which led to the overflow of the Deccan." According to Cowper Reed, " the date of the dissolution of the great continent (Gondwanaland) is not precisely determined, but it was a process of many stages, and was not simultaneous or uniform over its whole extent..... In India, the culmination of the development of the fissures with a general east-west trend took place at the end of the Cretaceous period, and the molten material of the Deccan eruptions welled up through them and spread out over the surface as horizontal sheets of lava, or formed dykes, the parallelism of which to the faults has often been noticed. The truncated edge of the table land in South Africa (where the marginal faults involve the Tertiary beds) and the similarly abruptly broken edge of the volcanic plateau of the Indian Peninsula prove that some of the downward movements took place much later, and in post-Cretaceous times....The outlines of South Africa and of the Indian Peninsula have been determined by long faults with downthrows respectively to the east and west. The structure of the sub-oceanic floor supports this view of their origin."

Thus at first sight it would appear that we are not yet sure as to with which of these two diastrophic movements we should associate the Deccan Trap eruptions; but actually there will be no such difficulty if we recognise the possibility that these two events—the breaking up of the Gondwanaland, and the upheaval of the Himalayas—were themselves probably in a way correlated. We know quite a lot about the chronological sequence of the different stages in the Himalayan upheaval; but we do not know in such detail the different stages in the disruption of Gondwanaland. It is by no means unlikely that there is a certain amount of parallelism between these two manifestations of diastrophism, in which case the history of the Deccan Trap eruptions would naturally go hand in hand and be correlatable with both. Prof. Mathur had probably some such idea in his mind when he said in 1934— "The history of the Deccan Trap period is intimately connected with the breaking up of the Gondwanaland and the elevation of the Himalayan chain." Similarly Prof. Sahni, who said in 1938: "The available data, geological and oceanographic, indicate that the northern part of the Arabian Sea covers a foundered tract of land which once connected India with Arabia and Somaliland. The foundering appears to have resulted from block-faulting due to compression possibly related to the Himalayan orogenic forces." It may also be noted that in their paper on the Floor of the Arabian Sea, Wiseman and Sewell make the following important statement: "It seems highly probable that the floor of the north-west part of the Indian Ocean, as we know it to-day, assumed its present form as a result of compression in Tertiary times, probably contemporaneously with the upheaval of the Alpine-Himalayan mountain system, and the arcs of the Malay Archipelago and of the formation of the Rift Valley. Subsequently in Pliocene or Post-Pliocene times the area of land that once filled the triangle now bounded by the northern part of the East African coast and its continuation, the south-east coast of Arabia, the Baluchistan coast, and west coast of India, became separated off by a series of faults and was submerged to its present depth."

From a review of all these considerations and having regard to the duration of these eruptions as gathered from the geological history of the Deccan Trap period, it seems almost impossible to compress the entire eruptive history within the confines of a relatively small period of time represented by the eocene system. According to Blanford, the duration of this eruptive activity was between the cenomanian and the danian of the cretaceous. This period of time—cenomanian to danian—is admittedly very much longer than that covered by the eocene system; and if on present evidences we differ from Blanford and have fixed the *lower* age limit as not cenomanian but lower eocene, it follows that starting from this point and providing for

the necessary duration of time for the geological history of these eruptions, the *upper* age limit of the trap formation as a whole must extend far into the Tertiary. Thus it would appear that, as Dr. Geddes puts it, "the Tertiary 'land storm' which led to the upheaval of the marine sediments and of the underlying beds of Tethys, the ancient central sea, and their folding into the Himalayan ranges dividing the uplifted Tibetan plateau mass from the Gondwanaland plateau to the south, would be accompanied, not preceded, by the beginnings of rifting in this plateau mass and by the recurrent outflow of sheet upon sheet of lavas welling through rock fissures."

It is not unlikely that further and fuller studies from the stratigraphical and palæontological points of view, which I think should now be actively undertaken, will ultimately confirm this conclusion. It is particularly necessary now to make a thorough study of all the fossils in the upper inter-trappean beds found near Bombay; it must be admitted that these have been badly neglected and full justice has not been done to their testimony as age indicators. There is certainly no support or justification for the statement that "there is a *general resemblance* of the fossils in the uppermost inter-trappean beds at Bombay to those in the Central Provinces." On the other hand, as Cowper Reed points out, "Plants, entomostraca, mollusca and reptilian and amphibian remains are found in them, but none of the characteristic fossils of the lower inter-trappean group." We should also at the same time look for the possible occurrence of fossiliferous inter-trappeans (looking carefully for microfossils also) at other stratigraphical levels between Nagpur and Bombay in the trappean succession. In any case, it seems undesirable that we should commit ourselves at present, directly or indirectly, to the view that the Deccan Trap eruptive activities were confined to the eocene only. In the present state of our knowledge, I think the upper age limit of the Deccan Trap formation must atleast be left as an open question.

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Dr. A. G. K. MENON

# Presidential Address: 1950

DELIVERED BEFORE THE ZOOLOGICAL SOCIETY OF INDIA IN THE ANNUAL MEETING HELD AT POONA ON 4TH JANUARY 1950.

BY **S. L. HORA,** D.Sc., F.N.I., F.R.A.S.B.,
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(Delivered 4th January—Received 15th February 1950)

CONTENTS



## I—Review of progress of the Society during 1949

The Zoological Society of India has had another successful year of its existence. Its membership has nearly doubled for it has arisen from 149 at our last Annual Meeting to 275 now. There is still room for much further expansion and we hope and trust that our members will spare no pains to enlist more zoologists and others interested in the Animal Kingdom. With our membership spread over a dozen foreign countries, we are international, not only in our scope, but also in our outlook and shall indeed welcome more members from outside countries.

We are grateful to Dr. S. C. Law for becoming our first Benefactor by paying Rs. 500/- towards the Society's fund. His brother, Dr. B. C. Law, has very kindly contributed Rs. 250/- towards the publication of an article entitled "Some observations on the knowledge of ancient Hindus regarding animal life during the early Jain and Buddhist Period, *Circa* 600 B.C." in our *Journal*. We are very thankful to him for this help.

In electing Lt.-Col. R. B. Seymour Sewell, F.N.I. F.R.S., one of our Life Members, as our first Honorary Fellow we have paid a rightly-deserved compliment to a person with whom the advancement of zoological science in India is still a burning desire. I met him in London just a couple of months ago and found him extremely enthusiastic and helpful in all matters pertaining to Indian Zoology. In honouring him, the Society feels greatly honoured itself.

The Society has honoured 39 of its members by electing them as Foundation Fellows and I take this opportunity to extend to them my heartiest congratulations. They are the torch-bearers of the Society and we expect much towards our improvement through their scholarship and service to the Society.

The number of Local Branches is now 6 against 3 at the end of last year. The usefulness of our Society, until we have a permanent home of our own, will lie in the activities of our Branches and, therefore, I wish to lay special emphasis for the establishment of local branches at all University centres and other centres of zoological research. We have branches at present in Calcutta, Banaras, Bareilly, Hoshiarpur, Annamalainagar and Mandapam. We extend to the Branches our good wishes and felicitations and request them to keep us fully informed of their activities so that the Annual Report can be made as complete as possible.

The financing of the publication of the *Journal* has been our greatest nightmare and we are not out of the woods yet in this respect. There is a proposal to increase the Membership Fee and to make it inclusive of the *Journal*. We have already economised by going to a cheaper press in Calcutta. We have received a larger contribution from the National Institute of Sciences of India this year, namely Rs. 800/- against Rs. 700/- for 1948. The National Institute of Sciences of India has kindly agreed to recommend our case for Government grant in aid of

publication, but in view of the prevailing financial stringency much cannot be expected. We are thankful to the National Institute of Sciences of India for its kind interest in this infant society and we hope it will continue to encourage us in our endeavour to make zoology a living science in India. I have already referred to Dr. B. C. Law's generous contribution of Rs. 250/- towards the *Journal.* In spite of all this, an emergency still existed and I set up a Committee of 10 members consisting of the President, Secretary and Treasurer, as ex-officio members and Dewan Anand Kumar (Solan, Punjab), Dr. D. V. Bal (Bombay), Mr. K. N. Gupta (Banaras), Dr. M. A. Moghe (Nagpur), Dr. N. K. Panikkar (Mandapam), and Mr. S. C. Verma (Allahabad), as members with Dr. T. J. Job (Calcutta), as Convener and Secretary, to suggest measures for imporving the Society's finance with a view to maintain our publications. The Committee has advised me that efforts should be made to secure advertisements for the *Journal* and that a regular campaign should be made to secure more members, benefactors and patrons. Attempts should also be made to secure donations. I wish to express the gratitude of the Society to Prof. M. A. Moghe who has made a donation of Rs. 50/- towards the finances of the Society in response to this appeal. Donations of Rs. 50/- and Rs. 15/- for publication fund have also been made by Dr. M. A. M. Quadri (Aligarh), and Dr. K. S. Misra (Calcutta), respectively.

Our *Journal* has been favourably commented in India and abroad, and we feel that in its publication we shall be serving real need of Indian zoologists.

More than the efficiency of the begging bowl, I believe in self efforts and to raise funds I have undertaken to organise a Zoological Exhibition at Calcutta early in February in the Indian Museum. We have invited all organisations in Calcutta interested in any aspect of zoological science to join us in making the exhibition a success. The Trustees of the Indian Museum have already accorded their kind permission and the authorities of the Fine Art Exhibition have kindly promised to leave their structures and lighting up arrangements in tact for our Exhibition. We shall be working ourselves as guides and thereby explain to the general public the impact of zoology on human life. Thus, besides raising funds we shall be fulfilling the main objective of the Society viz., "diffusing zoological knowledge among people." I am sure you will all join with me in expressing our deep gratitude to the Trustees of the Indian Museum and the authorities of the Fire Art Exhibition for the great encouragement they have given to us for holding this Exhibition.

I was your soldier President, for your first objective was to put the Society on a firm footing and I believe this objective has been partly attained as will be evident from the fact that when the present Executive took over office in 1947, the total number of members was 31; now it is 275. The number of Life Members has increased from 10 to 29. The Society has been able to bring out two issues of the *Journal* at a cost of about Rs. 4000/-. The third issue is in the press and still we are not bankrupt, as was once apprehended when the *Journal* was started. We took over with an opening balance of Rs. 1817/0/3 which represented mostly life membership subscriptions and our grand total to the end of the year is now expected to be about Rs. 8700/-, though the working balance will be about Rs. 1000/-. In this work, I had the fullest co-operation and assistance of the office bearers and the members of the Committee and I wish to thank them severally and collectively for their manifold kindnesses and courtesies. I wish particularly to mention the services rendered by our Secretary, Hony. Major Dr. M. L. Roonwal, and Treasurer, Dr. B. S. Chauhan. But for their hard work, it would not have been possible to attain our present position. On behalf of the Society and on my own behalf, I express to them our sincerest gratitude and hope that they will continue to give time and attention to the Society for some years to come. Mr. M. N. Datta has done a great deal of work for the Society behind the scenes and though he shuns limelight I cannot help recording Society's sincere thanks to him for his services.

Having briefly surveyed the work of the Society during 1949, your President is expected to address you on some subject of his research or of general interest to the zoologists in this country. I have selected "Oceanographic Studies in Indian waters" as the subject for the technical part of my address because it is of vital importance for the development of the nation as a whole and of special interest to zoologists, both pure and applied.

## II—Oceanographic studies in Indian Waters.

There is no institute of oceanography in the Indian region and, therefore, the study of the Indian Ocean has so far received very little attention. Realising this dificiency for the proper development of marine fisheries in India, the Zoology and Entomology Section of the Indian Science Congress, early in 1946, passed the following resolution:—

> "The Section of Zoology and Entomology wishes it to be fully realized that the study of oceanography, both in its physico-chemical and biological aspects, is of greatest importance for the development of marine fisheries in India, and urges on the Government of India the desirability of negotiating with Governments of the countries bordering on the Indian Ocean so as to secure their close co-operation and collaboration in working out a joint scheme of setting up an Institute of Oceanography for the study of the Indian Ocean. A knowledge of what is taking place in the Indian Ocean must be one of the bases for the proper regulation of fisheries in all surrounding countires."

I brought up the above subject for consideration at the British Commonwealth Scientific Official Conference in July 1946 (*vide* O.C.62: Oceanography in the Indian Ocean) and apprised the Conference of the state of marine studies in the Indian Ocean and proposed that the countries of the Commonwealth should organise an institute jointly. For the location of such an institute, Ceylon and the Andaman Islands were suggested as possible sites, and its scope was to include both physico-chemical and biological studies. Col. Sewell, at the same Conference, dealt with the "Oceanographical problems in the Indian Ocean".

The Committee on Oceanography and Fisheries of this Conference met on the 16th and 17th July, 1946, and passed the following resolution about the study of Oceanography in the Indian Ocean:—

> "4. Urges on the Governments of the countries bordering on the Indian Ocean the desirability of close co-operation in studying the oceanography of that ocean. It suggests that such co-operation might be greatly facilitated by the establishment of an Institute of Oceanography in a suitable location, under the joint control and support of the Governments concerned."

In 1946, the UNESCO's Sub-Commission on Natural Sciences directed that the possibility of founding an Oceanographical and Fisheries Laboratory for the Indian Ocean should be explored. The International Commission on Oceanography also urged in 1947 that combined Oceanographic and Marine Biological Laboratory should be established in the Indian Ocean. The Indo-Pacific Fisheries Council of the F. A. O. at the Singapore meeting early in 1949 discussed the preparation of a co-ordinated scheme of Oceanographic Research for the South-East Asia as a whole. Apart from these, the Government of India have a scheme for the establishment of a Fisheries and Marine Biological Station in the Andamans which will also carry out Oceanographic research. The "Oceanography Committee" of the Central Board of Geophysics in India has been set up and, pending the decision of the Government of India regarding any Oceanographic organisation of its own for the study of the Indian waters, this Committee contemplates joining the National Institute of Oceanography, London. It has already met and suggested the following priorities for ocean work:—

1. Establishment of Tidal Observatories at ports which are under development, including observations such as salinity, temperature of coastal waters, etc.
2. Biological work, with special emphasis on fisheries, as for example, collection of plankton, observations on food supply, etc.
3. Physical observations, observations on sedimentation, and topography of coastal shelves.
4. Magnetic and gravity observations in and around the Islands in the Bay of Bengal and Arabian Sea.
5. Echo sounding.
6. Collection of water, biological and geological samples.

It was also decided at this meeting that two areas, such as the Gulf of Cambay and the head of the Bay of Bengal with the coral reefs round Mandapam, may be provisionally selected for initiating investigations and the laboratory at Mandapam should be used for the examination of specimens and material collected.

To complete the story of world interest in Indian Oceanography, reference may here be made to the International Commission on Oceanography, of which Lt.-Col. R. B. Seymour Sewell, F.R.S., lately Director of the Zoological Survey of India, is the Secretary. This Commission was set up in 1947 by the combined action of the International Unions of Biological Sciences and of Geodesy and Geophysics: one of the objects of this Commission has been "to invite the co-operation of a leading Scientist in all those countries, that possessed a sea-coast and were interested in the study of oceanography, and ask him to keep in touch with the Commission and keep it informed regarding any oceanographical investigations that were being carried on or were contemplated in both physico-chemical and biological branches". The Commission were pleased to appoint the writer their Correspondent for India.

It would appear from the above that there is almost a world-wide interest in the study of the Indian Ocean but there is practically no co-ordination between the agencies interested in the work with the result that an average zoologist becomes bewildered by the mass of resolutions and paper schemes. My present position as Director, Zoological Survey of India, requires that I must know something of Oceanography though it is not directly in my line, so I availed myself of the opportunity of a recent visit to the U.S.A. to educate myself on this subject. I visited the Oceanographic Institute at Woods Hole, the Bingham Oceanographic Laboratory of the Yale University at New Haven, the Scripps Institution of Oceanography of the University of California at La Jolla and the School of Fisheries at the University of Washington at Seattle. At Woods Hole I saw the various modern devices used in the study of the ocean and marvelled at the leeway India has to make up in this science. Perhaps it may interest you to learn something about the fish shoals detection devices, and, to save time, I shall narrate just a few.

I was not aware, and I am sure most of you are not aware also, that sometimes there is as much noise on the ocean bed as there is in an Indian bazaar. Through apparently simple devices, these sounds are recorded and, by making collections at various depths, have been correlated with the types of animals making different kinds of noises. We listened to gramophone records and were informed of the types of animals that made those noises. Photographs can be taken at different depths for the study of the sea bottom or its fauna at various depths. Echo sounding apparatus and its application for the detection of fish shoals are now common knowledge and hardly excite much attention in western countries.

At the Yale University, I had long discussions with Dr. E. F. Thompson and learnt that in a University Course for a general outline for Oceanography, the students are given lectures on the following subjects:—History (2); oceans of the world (2); ocean floor (2); composition of sea water (2); salinity and temperature (general distribution) (2); heat balance (1); oceanic circulation (4); plankton and productivity (6); inter-relationship of physico-chemical enviornment and animal life (5); bathymetric distribution (2); whales (2) and modern trends (2). These 32 lectures are delivered at the Yale University by 4 teachers, each specializing in certain lines of study.

The Scripps Institution of Oceanography, perhaps the largest and the best equipped in the whole world, has a staff of 54 officers and imparts instructions in "marine meteorology, biochemistry, geology and microbiology; physical and chemical oceanography; phytoplankton, marine invertebrates, and biology of fishes".

I have given the above details to impress on you that oceanography is not a single science but a combination of several sciences. In short, it is a field of endeavour, the achievements of which can be of the greatest interest and importance in various directions, both academic and applied. From this it follows that any institute we may wish to set up in the Indian Ocean should have adequate staff and sufficient and up-to-date equipment right from its commencement, for continuity of observations is most essential in oceanographic studies. For financial reasons and lack of trained personnel, it will be necessary, therefore, to define at the very outset the objectives of the proposed institute. If we want only the knowledge of the physics and chemistry of the ocean then the Institute will subserve military, naval or air-defence problems and might enrich meteorology also. Such an objective will always have some applied aspect in view and general and fundamental basic research will be excluded. If, on the other hand, the objective be the study of the ocean as a biological environment, then the endeavour can either be applied to practical problems of the harvesting of the seas for improving human nutrition and raising his standard of living or it can be purely academic.

Another important consideration in oceanographic work should be that, in the initial stages at least, it should not be spread over a wide area but should be restricted to practicable limits for a simple, integrated programme, small enough to permit complete studies, and large enough to provide significant results.

As soon as an institute is planned for a certain region, attempt should immediately be made to collate and codify all existing oceanographical literature of that region. This will enable the various problems to be seen in their proper perspective and will save much time and labour of the technical staff. Furthermore, students will be able to take up the problems immediately which will lead to a great expansion of knowledge.

Whatever may be the objective—academic research and teaching; military and naval requirements; meteorological requirements; geology and geodesy of the ocean bottom; or development of fisheries resources—the lines of research will have to be phased in such a way that there is a progressive development with room for adjustment as the work proceeds. Thus, there should be flexibility of programmes of work. Full plans should be drawn up at the beignning and total costs calculated, though it may be necessary to make a small beginning. The programme of work will generally have the following four phases:—(i) Observations and codifications of existing knowledge (*descriptive phase*), (ii) Generalizations arising out of observations (*analytic phase*), (iii) Prediction., (iv) Controls.

It is absolutely necessary that there should be a continuity of observations over long periods, otherwise the whole purpose of research would be defeated. The data must be collected with the idea of establishing correlations in the variations and fluctuations of different factors. As the progress made leads to the development of the next phase, it is also essential that there should be no slackness in work under the earlier phases. The staff, library and equipment should be adequate at all times to handle the problems under investigations and team spirit should be encouraged to the highest degree possible. The results obtained and techniques developed by working on small representative areas could later be applied for the Survey of the whole area.

During discussions at the Scripps Institution of Oceanography on the establishment of a new institute for the Indian Ocean, the following seemed to be the general lines of advice:—

1. The objective should be the study of the ocean as a whole, both in its physico-chemical, geological and biological aspects, without any particular bias for applied researches of military, naval, meteorological, geological, geodetic and fisheries nature. The ocean should be studied for its own sake.

2. For the establishment of such an institute, key personnel will be the first

necessity, and this was felt to be really a difficult task, as all-round good oceanographers are few and almost non-existent in the region of the Indian Ocean.

3. Training of personnel could be undertaken in the following ways:—
(i) The appointment of a "Naturalist" (in place of a Surgeon-Naturalist) to the Marine Survey of India should be revived before the Survey work gets into operation, and the Government should define it as a policy that such oceanographic work as may lie within the power of the Naturalist to do without undue interference with the work of the Survey Proper, will be regarded as part of the function of the Marine Survey. (ii) Oceanographic studies should be encouraged in the Universities favourably situated for this work and foreign teachers should be recruited on short term basis to organise teaching and academic research. Sloop-type vessels available with the Indian Navy could be used for preliminary researches. (iii) Students showing special aptitude for oceanographic work should be sent for overall training to the Scripps Institution of Oceanography. (iv.) One of the top U.S.A. oceanographer should be invited to India to take stock of the things and advise Government as regards location, programme of work and equipment for any new institution that may be started.

It will be seen from the above that research ships and expensive equipment, though highly desirable for any long-range programme of oceangraphic researches, are not immediately necessary. It will take a few years before India can boast of having any oceanographer of her own. Let us make good our deficiencies by well-planned, progressive, evolutionary programmes and not start by incurring heavy expenses, for any failure in the initial stages will retard the progress of oceanographic work in India. Five or even ten years in a nation's life are not much, so we should be in no haste. Let us invest in men in the initial stages and not in material which cannot be properly used under the existing condition of our knowledge.

The oceans of the world are three times as extensive as the land and how long have we taken to understand even a small part of the land! By their very nature, oceanographic studies are more difficult to pursue and will need greater application, human ingenuity and thoughtfulness to tackle them. Let us then lay a broad-based foundation for our present and future studies, building on existing knowledge and enlarging it by scientific research conducted under Indian conditions.

## APPENDIX

### VIEWS OF SPECIALISTS

Copies of the above note on "Oceanographic Studies in Indian Waters" were sent to specialists in the U.K. and the U.S.A., with whom the writer had the privilege of having had personal discussions on oceanographic studies. Since the views received are of permanent value and now constitute a Symposium on the subject, they are appended herewith with the kind permission of the authorities quoted.

### COL. R. B. SEYMOUR SEWELL'S VIEWS

*Extract from a letter dated the 6th December, 1949:*—

You see oceanography in Indian waters, apart from the biological work of the "Investigator" and the "Mabahiss" is practically an untouched subject. We know practically nothing in any of the various branches of Oceanography so far as this area is concerned and any organised research will have to be carried on in close collaboration with various Government Departments as for instance (a) the study of the bottom deposits and recks in collaboration with the Geological Survey of India and the Geodetic Branch of the Survey of India, (b) the study of surface and deep-sea currents in close collaboration with the Fisheries Department: and both these lines of research will require the collaboration of the Indian Navy and especially the Marine Survey of India, when this starts to function again.

I would press very strongly for the appointment of a 'Naturalist'—to take the place of the old 'Surgeon Naturalist' to the Marine Survey of India, and get the Government to state definitely that such Oceanographic work, as lies within the power of the Naturalist to do without undue interference with the work of the Survey proper, must be regarded as part of the function of the Survey. If this can be done before the Survey gets started it will be much easier to get this line of work recognised than will be the case if the Survey gets going and then an attempt is made later to introduce this branch of work into their programme.

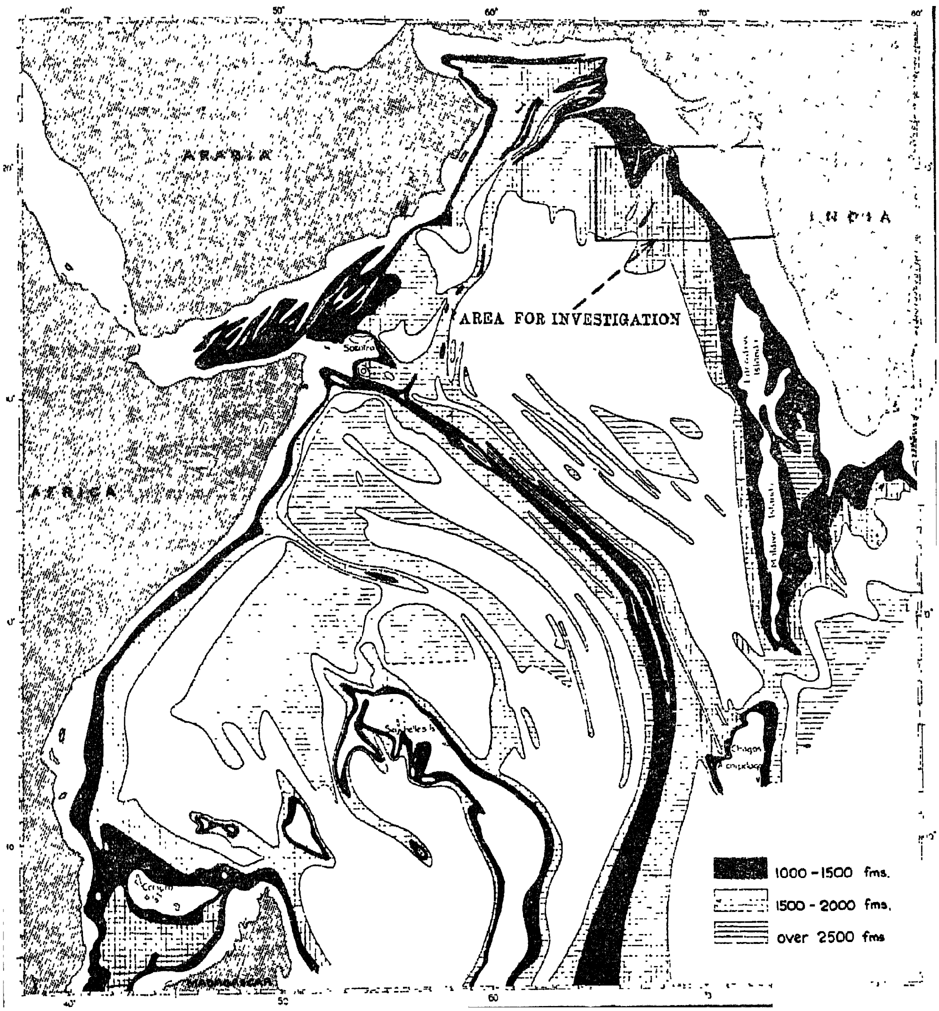
*Extract from a letter dated the 6th January, 1950.*—

The study of the Indian Ocean or more precisely, the northern part of it, comprising the Arabian Sea and Bay of Bengal regions, has in the past received considerable attention as regards its Zoological aspect. Since 1884, a succession of Surgeon-Naturalists to the Marine Survey of India have conducted researches into the fauna of the deep-sea, and this work only came to an end in 1926. Professor J. Stanley Gardiner conducted two Expeditions to the Coral Islands of the Arabian Sea region, in 1899 to the Maldive and Laccadive region and in 1905 to the Chagos Archipelago and the coral regions to the west between the Chagos and the African coast. In this line of research the work of Col. A. Alcock was of great importance, resulting in the production of a number of extremely valuable Monographs.

Several Expeditions have crossed the Indian Ocean and have added their quota to our knowledge, such as the 'Valdivia' and the 'Dana' in the tropical region and the 'Gauss' in the south-west area; while a series of Royal Naval Survey ships, as well as Cable ships, have added to our knowledge of the bottom topography.

In more recent years there was the John Murray Expedition to the Arabian Sea region.

But little systematic work has as yet been done on certain aspects of Oceanography in these waters, especially on (1) The depth of the bottom deposits, the composition, rate of deposition and the chemical and mineralogical character of the deep-sea Oozes, (2) The chemical and physical character of the sea-water at all depths, and the movements of the deep water masses, and (3) The Plankton in all its aspects; while nothing whatever has been done to determine the depth and character of the earth-crust below the water masses.




*Letter dated the 13th January, 1950.*—I have been thinking over the possibilities of India making a start in Oceanographic Investigations. You realise, of course, as well, if not better, than I do the immense difficulties that face you at the present moment, expecially:—

(1) The lack of any Research Vessel.
(2) The lack of up-to-date equipment, specially in such lines as bottom-coring and seismological observations on the depth of the bottom deposits.

(3) The absence of any experienced personnel for work at sea.

(4) The great scarcity of scientific experts to work up the material that may be obtained.

Clearly, in order to make a start a relatively small area should be selected and at the commencement only certain lines of work should be attempted in the first cruise, but in subsequent cruises other important lines of work should be added, as trained personnel and equipment became available.

At the start I would suggest that attention be paid to:—

(i) Close mapping of the depths by echo-sounding.

(ii) Obtaining cores of the bottom deposits by means of heavy sounding tubes, such as the "Bigelow" tube used by the John Murray Expedition (*vide* John Murray Expedition Sci. Reports Vol. I. No. i, p 10). It should be possible to improve on this by making the stream-lined weight heavier, say 150 or 200 lbs. and by lengthening the bottom coring section to 9 feet.

(iii) Water samples and Temperature observations at standard depths and at definite times of the day to detect any daily change-over of the upper layers and the possibility of upwelling of deep water.

(iv) Observations on the Plankton, especially of the upper strata at definite times of the day to detect daily vertical migration.

(v) Mid-water and bottom Trawling whenever possible.

Regarding the area to be investigated, I think the the Gulf of Cambay and the seaward area, say from the coast out to Long. 65°E and between Lats. 17° and 21°N. The relative proximity to Bombay would also be advantageous. This will include the area of the Continental shelf, where observations will be extremely valuable for Fishery Research and the whole length of the Continental slope down to about 2000 fathoms with the possibility of finding a submarine gully or gullies off the mouth of the Narbadda River.

*I.—Provision of a suitable vessel.*

A Sloop of the Indian Navy might possibly be converted into a Research Vessel without any very great expense. She would have to be altered so as to provide a laboratory and cabin accommodation for say 3 scientists: a Geologist for bottom sampling, a Chemist for Water-sampling and a Biologist for Trawling and Townetting. The vessel should be equipped with Supersonic sounding apparatus and one of the ships Officers should be a trained Surveyor for mapping the bottom.

She should also be provided with:—

(i) A heavy trawling whinch and about 3000 fathoms of Trawl warp.

(ii) A light Winch for Hydrographic work and about 2500 fathoms of Hydrographic wire.

(iii) Reversing water bottles of the 'Ekman' type, A Nansen-Petterssen Insulated water bottle. A supply of protected and unprotected Thermometers. Secchi disc. Comparator for Ph. determination.
Comparator for Phosphate determination.
A supply of glass bottles, spring-stoppered for storing water samples.
Burettes and chemicals for estimating salinity, if sufficient laboratory space can be provided on board for these estimations to be made.

(iv) The necessary trawls and dredges, etc.

*II.—Investigations to be undertaken.*

(a) Close mapping of the sea-floor by the echo-sounder and observations to be carried on to detect any reflecting layer, such as one caused by shoals of fish, and the presence of a migrating reflecting layer, such as that found by the American scientists in the Pacific between the surface and a depth of 350-450 meters. If such a reflecting layer be found, investigation of the fauna at the same depth by the mid-water trawl.

(b) The nature of the sea-floor with special reference on the Continental shelf to the presence of rock or coral masses, the knowledge of which would be of great value to Fishery work, and these might be detected by variations in the type and intensity of the echo and by investigations by the heavy dredge. If gullies are detected in the Continental slope attempts should be made to obtain rock from the sides and bottom by means of the heavy dredge. All cores should be cut down the middle of their length and be carefully stored for subsequent examination so as to detect changes in the foraminiforal content, as indicating changes in climatic conditions.

(c) Hydrographic observations by means of reversing water-bottles and thermometers.;
At first observations might be confined to examination of

Temperature.
pH content.
Oxygen content.

but later samples be examined for

Nitrate and Nitrite.
Phosphate.
Silicate.

and eventually, for the percentage of metals such as

Iron, Manganese etc.

*III—Biological Observations*

These should be quantative as well as qualitative, with special reference to:—

(a) Daily or seasonal vertical migration.

(b) Intensity of population ,at definite levels, especially in the photo-synthetic zone and near the zone of minium oxygen-content.

(c) The life histories of a few of the more common inhabitants.

(d) Distribution and possible zonation of the fauna down the continental slope.

(e) The presence of an azoic area.

At the conclusion of a cruise all material should be distributed to selected scientists but I do not know to what extent such will be available under present conditions. The Fauna and Flora should be worked out by officers of the Zoological or Botanical Surveys or perhaps

by some one in the Fishery Department. The Rock Samples should be worked out by someone in the Geological Survey. The cores of the bottom deposits must be examined by more than one scientist: the Foraminifera should be examined at various lengths along the core by a Protozoologist, who is an expert in that group, while a mineralogist should study the mineral content at various depths, and a chemist should carry out analyses on the percentage of organic matter, calcium carbonate, etc. For this it may be possible to enlist the services of someone in the Chemical Department of a University, and finally the cores should be examined for their radium-content: perhaps Prof. Megnad Saha might be able to help in this work.

At some later stage arrangements should be made to examine the depth of the Submarine deposits and the nature of the rock beneath by the relatively new technique of Seismology.

At the present time one great difficulty will be the obtaining of the necessary apparatus, but possibly some of the apparatus that was formerly in use on the "Investigator" may still be available; though I much doubt it. And in any case, as soon as a Marine Survey has been re-established, steps should be taken to press the Government to implement the scheme, which received the approval of the Government when it was first put forward, to appoint a Naturalist to the Marine Survey to take the place of the former Surgeon-Naturalist and to take the necessary steps to provide him with such equipment as he requires.

It seems clear that this Oceanographic work will have to be begun in a relatively small way, with one or two cruises during the good weather period of the North-east Monsoon, but planned for a number of years. If too small a scheme is put forward the Government of India and the Indian Naval Authorities may think that it is not worth while expending money on modifying a sloop for the work.

I think that the first thing, or one of the first things to do will be to appoint a suitable Scientist to be in charge of the work and later, when some progress has been made, to be the first Director: it may be necessary to send him overseas for training and for this I think that the Scripps Institute, at La Jolla, would be the best place. Another expert that will have to be sent overseas for training will be the person appointed to carry out the seismological observations on the depth of the bottom oozes.

In conclusion I haven't been able to consult the Members of my International Commission on Oceanography as time would not permit, but I have asked for advice and have received it from

Dr. W. R. G. Atkins, F.R.S., of the Plymouth Laboratory.

Dr. J. N. Carruthers of the Hydrographic Dept. Admiralty.

Prof. E. C. Bullard, F.R.S., formerly of the Dept. of Geodesy in Cambridge.

Dr. G. E. R. Deacon, F.R.S., of the "Discovery" Staff.

*Letter dated the 3rd February*, 1950:—Your letter of January 20th, which didn't reach me till the 27th, didn't give me sufficient time either to do any serious thinking about your request for a scheme for an M.Sc. Degree in Oceanography, or to get a reply to you by the end of the first week in February.

I have done what I could and send herewith a suggested scheme for such a course, and a Note by Dr. H. O. Bull, of the Marine Laboratory, Cullercoats, Northumberland on the required equipment. You will get further information as to Equipment etc. from the List given in Vol. I, Pt. I. of the 'John Murray' Reports which details our Equipment on the "Mabahiss". I also wrote to the Dept. of Oceanography Edinburgh, but have, so far, had no reply.

The first thing that should be done, before any University can set up a course in Oceanography for an M.Sc. Degree, is to get an Oceanographer, who will organise the course: if he has had experience in Oceanography he will know what he requires in the way of a Laboratory and Ship, and Equipment for both, and if he *hasn't* had such experience he ought not to be appointed.

Even such a moderate course as I have envisaged—say for 2 years instruction, should have more than one lecturer as well as the Professor or Reader: the teaching Staff should include a Biologist, a Geologist and Geophysicist, and a Physico-Chemist, to deal with the different aspects of the Science and the work of the Professor or Reader should be to organise the course and to co-ordinate the instruction of the several lecturers, and instruct the students in the way in which each branch is influenced by the other branches.

*Synopsis of a Course of Study in Oceanography.*

I. The History of growth of the Science.

II. Geographical, Geological and Mineralogical Studies.

A. The Distribution of the Oceans and the Continental Land masses :—
   The Theories of Ocean formation.
   (a) The Permanence of the Ocean Basins.
   (b) The Wegener Drift Theory.
   A study of Coastal formations:—
   (a) Scarp faulting.
   (b) Deposition.
   (c) Erosion.

B. Changes of Sea-level at different periods of the Earth's history, especially during the last Glacial Period and subsequently.

C. The Configuration of the Continental Shelf and the Continental Slope.
   The causative agents that have produced the Slope. Subsidence of the edge of the Continent. Talus slope of deposition of continental detritus.
   The Occurrence and theories of the mode of formation of Submarine Canyons.

D. The Configuration of the Ocean floor.
   The use of Charts.
   The Mid-Atlantic and Mid-Indian Ridges.
   The geological composition of the basic rocks.
   Wire, Sonic and Super Sonic sounding.
   Gravity Observations and Seismological investigation of the Sea bottom.

E. The Nature, Distribution and Mode of formation of the Bottom Muds and Oozes,
   Their Chemical and Biological composition: Percentage composition with special reference to Carbonates.

Silicates.
Organic matter.
C/N. ratio.

Stratification of long Cores as evidence of climatic changes in the past.

The presence of Azoic regions and possible formation of Petroleum.

The formation of Nodules of various types:—
Manganese.
Barium.
Phosphatic.

Radio-activity of rocks and of ooze at different levels in long cores, as Evidence of age.

III. Chemical and Physical Studies.

A. Chemical composition of Sea-water.

B. Salinity and Temperature of Surface-water in different regions, Isotherms. Isohalines, and Isocrymes.

C. The principal ingredients in Salt Water and their biological role.
The Nitrogen Cycle :—
Ammonia, Nitrite and Nitrate. Calcium carbonate distribution, Phosphates and Silicates, Oxygem Content, pH.
Certain Metals.
Iron, Strontium, Boron.

D. Degree of Penetration of Light of different wave-lengths
The Photosynthetic Zone.

E. Chemical and Physical characters of Deeper water strats.
Changes of Salinity and Temperature with depth Thermal Stratification. Variation in Viscosity. Increase in Hydrostatic Pressure.

F. The Effect of Wind and the Rotation of the earth on the water masses.
The Surface Currents.
Convergence and Divergence Zones.

G. Deep Ocean Currents.
Their mode of formation and rate of travel.
The Production of Seiches.

H. Tidal Currents.

IV. Biological Studies.

Bacteriological, Botanical and Zoological studies.

A. The inter-relationship of Plants and Animals.
Diatoms, Marine Algae and Organic detritus and their place in Life-Cycle.

B. Plankton, Nekton and Benthos.

C. Zoo-and Phyto-Geographical regions and the Influence of
(i) Surface Currents and Deep Currents on distribution, and
(ii) Convergence Zones on limiting Distribution.

D. Effect of Temperature on limiting distribution and breeding areas.

E. Influence of past Climatic Changes and Epicontinental seas on Present-day Distribution.
Relict Faunas.

F. Zonation of Animal Life :—
Surface, Mid-water and Deep Influence of depth on Colouration,
Zonation in Coastal belt.
Vertical Migrations.
Feeding and Breeding habits.

G. General Studies of Marine Organisms of various types.
Corals : Distribution and types of Coral Reefs and Atolls.

H. Relationship between Oceanography and Fishery Research.

I. Investigation of Life-histories. Influence of Parasitisation.

V. Meteorological Studies :—
Relationship of Sea and Air Temperature.
Readings of Wet and Dry-Bulb Thermometers.
Barometric Pressure.
Variation in Wind Force and its effects on the surface water.

SUGGESTIONS REGARDING EQUIPMENT

Extract from a letter received from Dr. H. O. Bull, of the Dove Marine Laboratory, Cullercoats.

1. *Buildings, Laboratories etc.*
Laboratory should provide about 10 sq. ft. (with all services—electricity, gas, compressed air and vaccum at each working place), per student. Ample storage for chemicals and apparatus. A separate balance room with 1 very rough, 1 large good general balance (1 kilo by 1 mg.), and 1 first class analytical balance (Oertling's 100 gms, by 1/10th mg.). All necessary apparatus and chemicals, including tubes of Standard sea-water, to permit of all the usual determinations of Chlorinity, Density, and the various trace elements, pH, etc. A pH meter and glass electrode outfit would be desirable but not essential.

2. *Boat.* A short vessel, like a Scotch Yawl, between 33-40 ft. in length, fully decked, the wheel, house aft, winch and capstan, with 30-60 H.P. Diesel engine, can be bought fairly cheaply, and is economical to run and maintain. I don't think a large vessel is necessary for training and teaching purposes.

3. *Gear.* All the usual trawling, dredging, plankton, etc., nets. For a boat of the size given, a 7 faths. otter trawl, with 2' 6" boards is the maximum workable size, using commercial meshes. A 10 ft. beam trawl is plenty big enough if small-mesh work is contemplated. A Pettersen Grab and small bore plankton pump would be desirable. Sets of all the standard hydrographical gear, hand-winch, motor-wheel. Nansen-Pattersen water bottle reversing frames, together with all necessary thermometers, messengers etc.

Wherever possible I would buy all gear from
Laboratoire Oceanographique
Charlottenlund Slot
Charlottenlund, Denmark.

4. *Shore work.* A few elementary surveyor's instruments are required for levelling, traversing etc., i.e., measuring sticks, hand levels surveyor's tapes, prismatic compass etc. Usual collection of hand-nets, scrapers, collecting gear,

I also think that no one should be able to get an M.Sc. in Oceanography who is not completely familiar with the reading of charts, laying off of courses, taking bearings and general principles and (? of) navigation and the use of the usual meteorological instruments. This would mean all the usual charts, manuals and necessary instruments, i.e. sextant, dividers protractors, parallel rulers etc.

For Fish Investigations he would require measuring boards, projector for scale reading, scales for weighing, microscopes etc., and all the usual equipment of a biological laboratory."

2/ Dr. J. Daniel of the Dept. of Oceanography, Liverpool, writes

> "We are concerned only with Physical Oceanography and therefore require, as a preliminary to M.Sc. that students should bo Science Graduates with the following subjects :—Pure Mathematics and either Applied Mathematics, Physics or Chemistry.

### Dr. Daniel Merriman's Views

*Letter dated the 4th January, 1950.*—Dr. Thompson has to-day shown me your letter of December 27th and accompanying note on "Oceanographic Studies in Indian Waters," and I take this opportunity to thank you for letting us peruse your conclusion and to tell you how much I enjoyed reading the note.

I hereby approve of the general tenor of your remarks, and my only suggestion (if you have the space) would be to enlarge on the subject of the training of students in oceanography. I feel very strongly that the progress we make in the future will be directly proportional to the number of young people entering the field with *breadth* of background and education. We need leaders-men with a full four years of undergraduate work including perhaps a major in Zoology, a knowledge of Chemistry through organic, Physics, Mathematics, etc., and four more years at the graduate level (leading to the Ph.D. degree) to strengthen the basic knowledge, gain greater breadth, and finally to allow specialization in the particular field of interest. Until it is widely realized that there are no short-cuts and that only through such a course of study will we obtain the world over a suffitcent number of leaders, we are not going to make the proper progress. It seems to me that India must face this problem squarely; she will perhaps import leaders from elsewhere at first (althought this will be difficut because most of them are so tied down), and she will have to invest generous sums in the education of promising young scientists abroad over long periods. If this is not done the return on other oceanographic investments in Indian waters is likely to be at very low rate. In this connection, I was very disappointed when the devaluation of the pound sterling prevented a young Indian student, whom we had admitted to the graduate school and who wished particularly to work with Dr. Thompson and myself, from coming here this fall. I do not feel that training through our M.S. degree (four years undergraduate work and 1-2 at the graduate level) is sufficient. If we want the best, we have to pay it initially, but in the long run the cost will be repaid many times over. Here at Yale we take relatively few students in the fields of marine biology, oceanography and ichthyology because we give each one much individual attention; but we hope to turn out the leaders in the field.

*Letter, dated the 8th February, 1950.*—You ask about the minimum oceanographic equipment needed at a university center to start oceanographic studies; I assume you mean apart from any sea-going facilities. You know, I think, that this small laboratory gets on very satisfactorily without owning its own vessel, and that for the areas which we work we use commercial trawlers, oyster boats, etc., to good advantage and at extremely low cost. For work on the high seas, however, we depend on the co-operation of the Woods Hole Oceanographic Institution. If you want advice about boats, I can do no better than to recommend you to Columbus Iselin. On the matter of oceanographic equipment, we have only the most ordinary things—water bottles, reversing theremometers, bathythermographs, plankton samplers, bottom dredges, meter sheaves, seines, ring nets, trawls, etc. As for laboratory equipment, just about everything needed at the outset is to be found in the ordinary zoology and chemistry laboratory-microscopes, histological materials, balances, titration equipment, glassware, calculating machines, etc. There are, of course, all sorts of special gadgets which may be purchased or built as the special occassion demands, but at the outset the basic requirements should not be great. In this laboratory less than 2% of our annual budget is allocated for laboratory equipment. However, because of our fortunate situation, we are perhaps not "typical," and I hope you will get information from others. In all events, by far the major cost will come equipping and operating a research vessel; the land work is relatively cheap.

I do not know whether or not you include books and periodicals under the term "minimum equipment." To my mind it would be of paramount importance to allocate sufficient funds for the purchase of journals, texts, etc. on a world-wide basis. Since oceanography touches on so many sciences, the library will have to be broad including material in such fields as botany, zoology, marine biology, ecology, physical oceanography, meteorology, geology, fisheries, etc.

### Dr. Ernest F. Thompson's Views

*Letter, dated the 25th January, 1950.*—By and large I think your overall plan is an extremely good one. I think you are very wise to invest in training personnel as your first step rather than in plant. In this regard I should like to emphasize that the quality rather than the quantity of your personntl is important I think you would make a much better bargain in training two or three men for five or six years abroad than in training a dozen for shorter periods. This of course comes back to Dr. Merriman's and my own belief that sound oceanographic and marine biological work can only be built on a sound basis of fundamental study in the Sciences. While undergraduate studies in these fields presumably have a place, our own experience of students so trained has been extremely discouraging. Personally and confidentially I feel that the emphasis on undergraduate courses in such things as Wildlife Management and Fisheries Biology in the States is a key to the mediocre quality of a great deal of work done here.

Nothing that I have said above should prevent your enlargement and expansion of your present activities in the marine field provided such expansion does not mean a crystalizing of a policy and assets. In other words, while you are training experts abroad you should continue to cultivate your home fields, but always with the view that the circumstances must be such that your trained experts can modify and expand in the light of their added experience. Another way you could facilitate growth in oceanographic fields could be by inviting foreigners to give short intensive courses to your better and senior students. Whether this could be arranged or not I do not know, but I am thinking of such men as Michael Graham in fisheries, Russel from Plymouth in plankton, etc.

*Letter dated the 11th April,* 1950:—I think the suggestion of establishing a station at the Andaman Islands should be approached with great caution. While these islands are strategically placed in the center of the area, their remoteness from centers of industry, universities and libraries would greatly handicap operations from there. The day when one or two oceanographers could happily isolate themselves from the world and perform a useful function has largely disappeared. Even the marine station at Woods Hole, within an hour of Boston, has found this isolation somewhat of a nuisance. In your case, where in the initial stages the station would be comparatively small, you will constantly be needing to call upon assistance from universities, physicists, geologists, chemists and biologists, and you will need facilities of machine shops, etc. These can usually only be obtained if you have ready access to a large town with an established university.

I still think the way to proceed is to train a few men thoroughly in this field, and I would think you should rely on these men after they have acquired their thorough training to make themselves largely responsible for the planning of the line your oceanographic researches will take. I am always rather skeptical of the plans made by "outsiders" for the future scientific development of a country. No country comes of age until it takes its own prophets seriously.

In seeking training for your students, it is important to obtain a *breadth* of view. Some schools of oceanography lean heavily on *theoretical* studies on *hypothetical* oceans. This type of training has limited application until the broader planning of your work has been completed. It is a pity Professor Sverdrup has now left the United States; he had the rare gift of keeping the theoretical people in useful channels.

In accordance with your request, your original memorandum was forwarded to Mr. Iselin. In replying to me he emphasized the need for adequate training in instrumentation. I think his point is very well taken and you would be wise to train some one specifically in this field.

## DR. R. VAN CLEVE'S VIEWS

*Letter, dated the 15th April, 1950.*—I have read with a great deal of interest your proposed oceanographic program. I concur with your statement that the most important factor is the acquisition of a staff of well-trained personnel. It would be most inadvisable to build and equip a station unless adequately trained scientists were available to operate it. In addition, oceanographic methods and equipment are being continually improved, and it is quite possible that many developments will occur between now and the time when you are prepared to put a staff in the field. It would indeed be regrettable if you should acquire equipment now that would be out-moded by much improved material later on.

With regard to the program as a whole, I am inclined to be somewhat skeptical of the types of programs which have been, and are now being carried on in most oceanographic institutes. From your statement, your primary interest in inaugurating such a program is the development of marine fisheries in India. This being the case, I believe that you should examine carefully your ultimate objectives, giving special consideration to the ends you wish to attain. If you want to undertake the study of oceanography for the sole purpose of increasing knowledge of the sea, you could pattern your program and the structure of your staff on almost any one of the oceanographic station now in existence. If sufficient regard were given to adequate training of your staff, you would undoubtedly obtain results that would be commensurate with your investment. However, in general such a program would not be effective in the development of marine fisheries. You have ample evidence at hand for judging the effectiveness of various programs conducted for many years in various parts of the world. If you will examine these programs and determine how much they have contributed to the development of fisheries, you will find that their contribution has been largely negative, and has usually followed rather than led such development. For example, the Scripps Institute of Oceanography has been operating for many years, and a fine body of knowledge having to do with many of the basic concepts of hydrography has been accumulated there. However, when the State of California was confronted with the need for effective action towards conservation of the Pacific sardine (*Sardinops caerulea*) the past operation of the Scripps Institute was on the whole of no direct value, and right now several hundred thousand dollars are being spent each year in an intensive hydrographical survey of the Pacific coast, and this study is being closely coordinated with the work in biology of the sardine. It would be my suggestion that a careful and detailed study of the various oceanographic programs be made, and their effectiveness in promoting the development of fisheries assessed. Only after such a study should plans be made for an oceanographic institute or program. I would certainly advise strongly against the adoption of a program that was developed by an oceanographer who was not also an expert in fisheries biology.

In my opinion, one of your first steps should be the development of accurate charts of your coast line and coastal fishing banks. Accurate surveys of the entire coastal areas, with frequent soundings, should be of primary concern. A general over-all survey of the nature of the ocean currents would probably also be of benefit. I can see no justification for undertaking a detailed study of any particular coastal region until it has been established that the area is of importance to fisheries.

Of vital concern in the development of your oceanographic program must be the building of an adequate staff to handle the work of fisheries itself. This staff should be established in two separate fields. One would handle the development of fishing techniques in Indian

waters which will be appropriate to the types of fishes available. They would also undertake the development of improved methods of preservation and handling of the catch and the improvement of marketing methods. Probably you should also include some such work as that now carried on by the U.S. Fish and Wildlife Service in teaching the more effective utilization of fish as food. The other branch should of course be the work in fisheries biology.

In relation with this second field of work, I should like to take exception to the statement made in the letter by E. F. Thompson of the Oceanographic Laboratory at Yale, regarding the underlying cause of much of the ineffective fisheries research now in progress. In spite of a surprisingly widespread opposition on the part of many biologists to practical fisheries biological investigation, this type of work is the only one which has really paid dividends in the form of fisheries conservation and production. It is true that in recent years many of our colleges have offered training in wildlife or fisheries management. However, these courses themselves have not been the cause of the ineffective fisheries work. As a matter of fact, they developed because of the general futility of the work carried on for many years by biologists who have what is generally considered to be sound biological training. It would be safe to say that most of the ineffective fisheries work at present is being conducted by men who had this so-called "sound biological training". I will agree that most of the training in wildlife or fisheries management now offered is worthless, but it is so because those who developed the courses and who teach them have had neither training nor experience in this field, and in general have no conception of the problems involved. Thus the fault is not that training in wildlife or fisheries management is being offered, but that in general the training is being given by men who are inadequately prepared in this field.

Improper and insufficient training of biologists is only one of the reasons for ineffective biological work. Another is poor leadership and direction by people who themselves improperly or inadequately trained, or in some cases by those who have no training whatsoever, and whose primary qualification is too often that they "know the right people" politically. The interference of politics also often results in preventing effective use of biological knowledge.

I believe you will find, through a careful study of the fisherits and biological work carried out in the past, and now being done, that the only *effective* results to be obtained will come if precedence is given to those phases of research that are most likely to produce *practical* results. Hydrographical and general oceanographical studies are useful in fisheries work only when they are planned and executed in close coordination with, and probably under the over-all direction of, a competent fisheries biologist who has a sufficient background to understand the problems of both fields.

As I stated before, I am assuming that the development of your marine fisheries is the main objective that you have in mind in establishing an ocernographic institute. If that is not the case, please disregard my rather lengthy remarks; but if it is true, I am sure that the most direct path toward a knowledge of fisheries will yield the greatest benefits in the long run.

# RAINFALL OF INDIA: A BRIEF REVIEW

L. A. RAMDAS

(*Agricultural Meteorologist, Meteorological Office, Poona*)

## 1. *Introduction*

A DETAILED discussion of Indian rainfall would fill volumes. In a short article like the present all one can attempt is to take a bird's-eye view of the subject.

A history of Indian rainfall is really a history of the well-known south-west monsoon. We have reliable records for about 60 years. As judged by these records, what is the dependability of rainfall in different parts of this vast sub-continent, and what are the chances of success of agriculture in different parts of the country? How often in a century is the monsoon rainfall so conspicuously in excess (flood) or in defect (drought) as to cause widespread havoc and failure of crops? Which are the regions in India with minimum of weather-risk? Do such risks occur at random or is there any regularity or law governing the time and place of their occurrence? What are the large-scale and long-term measures which the State can undertake in order to reduce weather-risks? In what parts of India will such developments be practicable? These are some of the questions which deserve consideration. In what follows, resort will be had to self-explanatory diagrams and tables so as to secure brevity.

## 2. *Physical and Climatic Features*

Figs. 1 and 2 show the distribution of the mountain and river-systems and of the normal annual rainfall of India. The areas of very heavy rainfall are to the windward side of the Western Ghats, the hills of Assam, and the great Himalayan barrier. These are the watersheds from which originate the major river-systems of the country. Elsewhere, in the plateau of the Deccan, the Gangetic plains of north India, and the plains of the Carnatic, the effects of orography are less pronounced or are completely absent and the rainfall is only moderate. In the north-west, the Punjab, NW. Frontier Province, Sind, Baluchistan, and the desert of Rajputana constitute the driest area of the country.

Table 1 gives the normal rainfall in different seasons of the year and during the year as a whole in the 30 subdivisions into which India may be divided (see Fig. 3). The four seasons are: winter, December to February; summer or pre-monsoon, March to May; monsoon, June to September; post-monsoon, October to November. In columns (2) to (5) the figures within brackets are the seasonal amounts expressed as percentages of the annual rainfall.

A study of these figures reveals at once that India is truly the land of the monsoons. With the exception of Kashmir, the NW. Frontier Province, and Baluchistan in the north and SE. Madras in the south, *a very large percentage of the annual rainfall over the country occurs during the south-west monsoon* (June to September). In the extreme north a

good proportion of the annual rainfall is contributed by winter precipitation, whilst in SE. Madras nearly half the annual rainfall occurs during the post- or retreating monsoon period (i.e. after September).

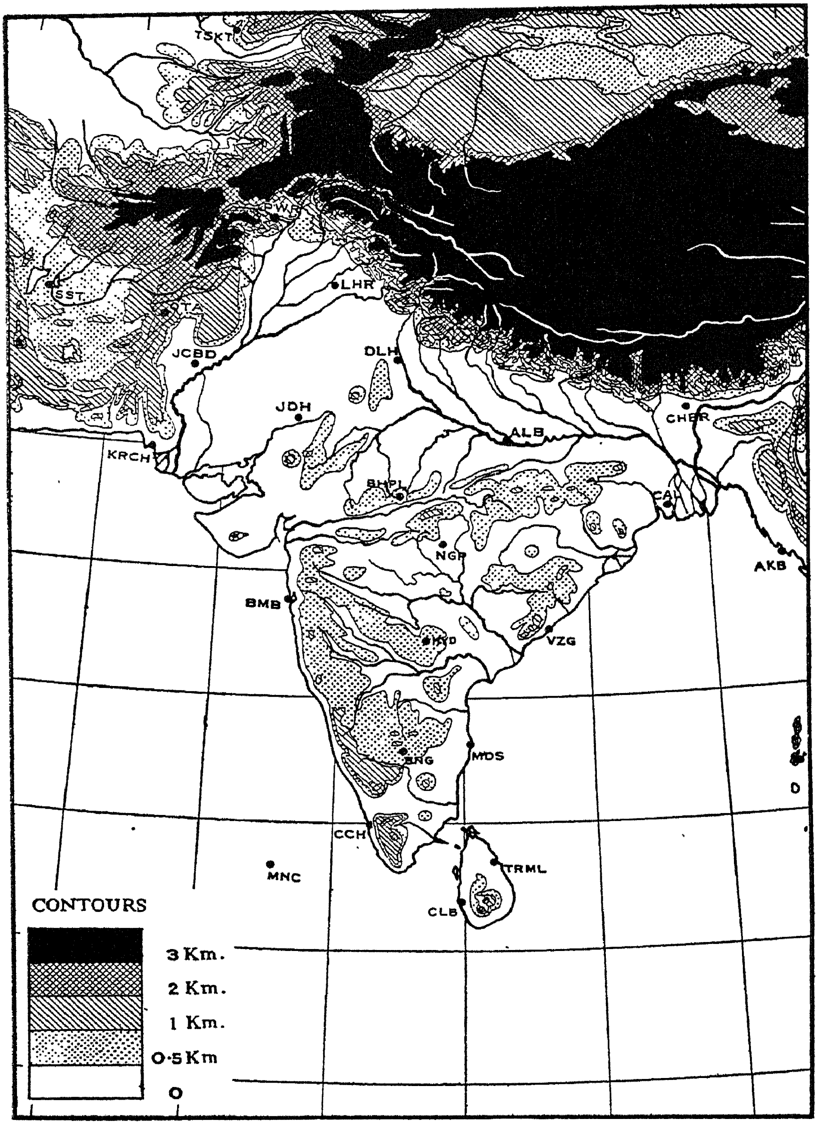



FIG. 1. Relief map of India.

Besides the setting in of the monsoon early in June, its extension into India during June and July, and finally its retreat southwards in September and October, we have also to consider the other major phenomena like cyclonic storms and depressions.

TABLE 1. *Normal Seasonal Rainfall in the 30 Rainfall Subdivisions of India*

| *Subdivision* (1) | *Winter Dec. to Feb.* (2) | *Summer or Pre-monsoon Mar. to May* (3) | *Monsoon June to Sept.* (4) | *Post-monsoon Oct. to Nov.* (5) | *Year* (6) |
|---|---|---|---|---|---|
| 1. Assam | 2·38 (2·4%) | 25·06 (25·7%) | 64·26 (65·8%) | 5·96 (6·1%) | 97·66 |
| 2. Bengal | 1·53 (2·0) | 12·42 (16·5) | 56·01 (74·5) | 5.17 (6·9) | 75·13 |
| 3. Orissa | 1 ·82 (3·2) | 5·62 (9·9) | 44·49 (78·2) | 4·98 (8·8) | 56·91 |
| 4. Chota Nagpur | 2·57 (5·0) | 3·64 (7·1) | 42·71 (83·4) | 2·26 (4·4) | 51·18 |
| 5. Bihar | 1·41 (2·9) | 3·30 (6·8) | 40·96 (85·0) | 2·54 (5·3) | 48·21 |
| 6. U.P. East | 1·53 (3·9) | 1·12 (2·9) | 34·44 (88·0) | 2·04 (5·2) | 39·13 |
| 7. U.P. West | 2·27 (6·0) | 1·36 (3·6) | 32·98 (87·8) | 0·97 (2·6) | 37·58 |
| 8. Punjab, E. & N. | 2·76 (11·9) | 1·89 (8·1) | 18·23 (78·4) | 0·37 (1·6) | 23·25 |
| 9. Punjab, SW. | 1·28 (13·7) | 1·36 (14·5) | 6·58 (70·4) | 0·13 (1·4) | 9·35 |
| 10. Kashmir | 9·12 (22·1) | 9·09 (22·0) | 22·19 (53·7) | 0·94 (2·3) | 41·34 |
| 11. N.W.F.P. | 3·36 (20·0) | 4·18 (24·9) | 8·65 (51·5) | 0·62 (3·7) | 16·81 |
| 12. Baluchistan | 3·50 (45·6) | 2·03 (26·4) | 1·89 (24·6) | 0·26 (3·4) | 7·68 |
| 13. Sind | 0·67 (10·4) | 0·41 (6·4) | 5·28 (82·4) | 0·08 (1·2) | 6·44 |
| 14. Rajputana, W. | 0·62 (4·8) | 0·56 (4·3) | 11·74 (90·0) | 0·12 (0·9) | 13·04 |
| 15. Rajputana, E. | 0·96 (3·8) | 0·78 (3·1) | 22·91 (90·9) | 0·55 (2·2) | 25·20 |
| 16. Gujerat | 0·22 (0·7) | 0·24 (0·7) | 31·46 (96·2) | 0·77 (2·4) | 32·69 |
| 17. C. India, West | 0·85 (2·5) | 0·47 (1·4) | 31·56 (93·8) | 0·75 (2·2) | 33·63 |
| 18. C. India, East | 1·44 (3·7) | 0·79 (2·0) | 35·05 (90·9) | 1·30 (3·4) | 38·58 |
| 19. Berar | 1·01 (3·1) | 0·96 (3·0) | 28·10 (87·4) | 2·07 (6·4) | 32·14 |
| 20. C.P. West | 1·47 (3·2) | 1·14 (2·5) | 41·04 (90·4) | 1·76 (3·9) | 45·41 |
| 21. C.P. East | 1·58 (3·0) | 2·10 (4·0) | 46·37 (89·1) | 1·99 (3·8) | 52·04 |
| 22. Konkan | 0·28 (0·3) | 1·85 (1·7) | 102·45 (93·7) | 4·75 (4·3) | 109·33 |
| 23. Bombay Deccan | 0·51 (1·7) | 2·13 (6·9) | 24·41 (79·1) | 3·82 (12·4) | 30·87 |
| 24. Hyderabad, N. | 0·67 (1·9) | 1·53 (4·4) | 29·51 (84·5) | 3·20 (9·2) | 34·91 |
| 25. Hyderabad, S. | 0·57 (1·9) | 2·10 (7·0) | 23·38 (78·1) | 3·88 (13·0) | 29·93 |
| 26. Mysore | 0·73 (2·0) | 5·47 (15·2) | 22·27 (61·8) | 7·54 (20·9) | 36·01 |
| 27. Malabar | 2·73 (2·6) | 12·61 (12·2) | 71·47 (68·9) | 16·93 (16·3) | 103·74 |
| 28. Madras, SE. | 4·76 (13·6) | 4·53 (12·9) | 12·01 (34·2) | 13·80 (39·3) | 35·10 |
| 29. Madras, Deccan | 0·74 (3·0) | 2·42 (9·9) | 15·27 (62·3) | 0·09 (24·8) | 24·52 |
| 30. Madras, Coast N. | 1·69 (4·2) | 3·44 (8·6) | 25·03 (62·3) | 10·00 (24·9) | 40·16 |

(1) *Eastern depressions:*—The fluctuations in the intensity of the monsoon itself are to a large extent associated with a series of depressions which mostly originate (or, when they are coming from farther east, strengthen) at the head of the Bay of Bengal and travel in a north-westerly direction across the country towards NW. India, causing heavy rainfall along their track. The frequency of such depressions is 3 or 4 per month during the monsoon months (June to September).

(2) *Western depressions.*—During the period November to May a series of western depressions enter India through Baluchistan and the NW. frontier and move eastwards across North India towards NE. India (Assam–Bengal). These depressions cause cloudy weather and light rains in the plains with snowfall in the Himalayas and are followed by cold waves. Their frequency is, on the average, 2 in November, 4 to 5 per month during December to April, and about 2 in May.

(3) *Cyclonic storms.*—The more severe cyclonic storms usually form in the Bay of Bengal and in the Arabian Sea in the transition periods April to June and October to December. They enter inland and cause considerable precipitation and damage due to high winds and, occasionally, tidal waves, in the coastal tracts. The mode of occurrence of

these storms and their favourite tracks have been discussed in the publications of the India Meteorological Department. On an average

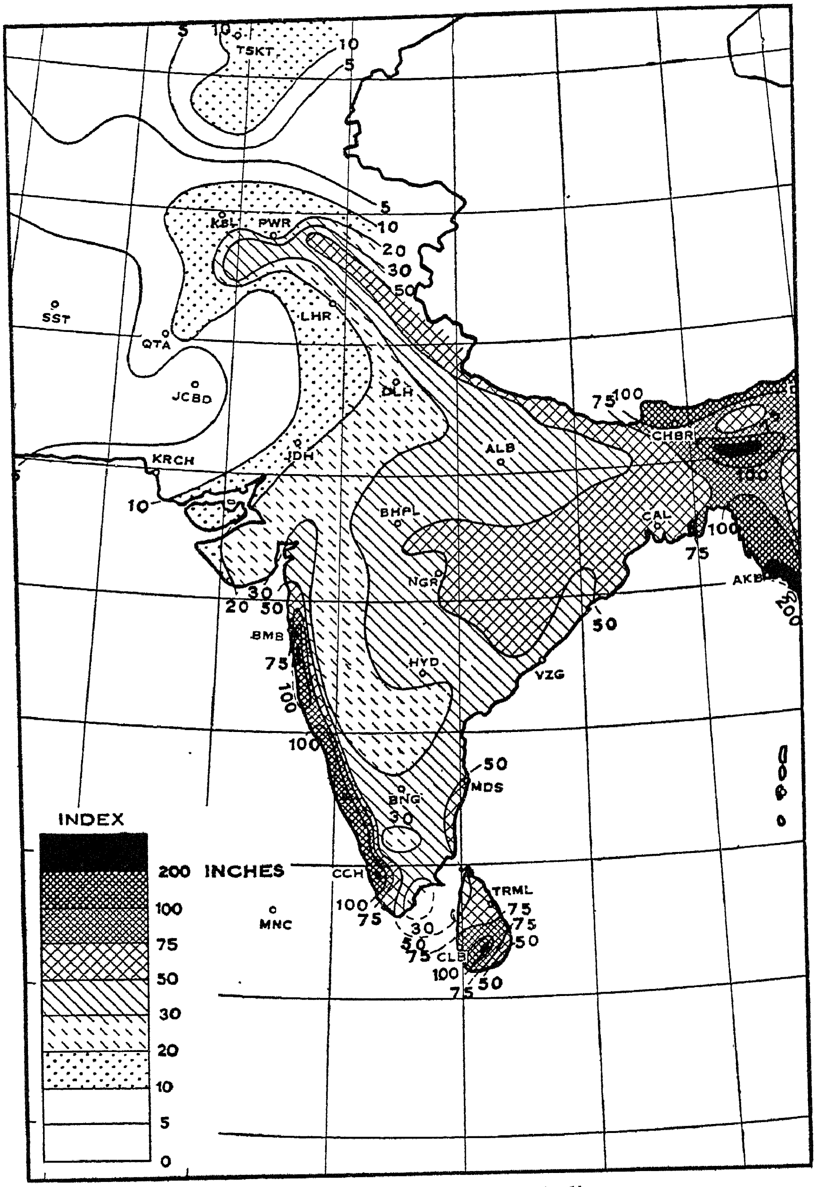



FIG. 2. Annual rainfall in India.

1 or 2 severe cyclones may be expected in the pre-monsoon period and 2 or 3 in the post-monsoon period.

### 3. *The SW. Monsoon*

(*a*) *Date of establishment.*—As is well known, the success of Indian agriculture depends mainly on the monsoon rains; the farmer looks

TABLE 2. *Date of Establishment of the SW. Monsoon along the West Coast of India*

| *Year* | *Travancore–Cochin* | *S. Kanara* | *Ratnagiri* | *Kolaba* |
|---|---|---|---|---|
| 1891 | May 27 | June 3 | June 19 | June 21 |
| 1892 | ,, 22 | May 24 | May 29 | May 31 |
| 1893 | ,, 22 | June 4 | June 10 | June 10 |
| 1894 | June 1 | ,, 2 | ,, 7 | ,, 7 |
| 1895 | ,, 8 | ,, 12 | ,, 14 | ,, 15 |
| 1896 | May 30 | May 31 | ,, 1 | ,, 1 |
| 1897 | ,, 30 | June 5 | ,, 7 | ,, 7 |
| 1898 | June 2 | ,, 3 | ,, 8 | ,, 8 |
| 1899 | May 23 | ,, 7 | ,, 9 | ,, 10 |
| 1900 | June 6 | ,, 8 | ,, 9 | ,, 9 |
| 1901 | ,, 1 | ,, 4 | ,, 7 | ,, 7 |
| 1902 | May 31 | ,, 6 | ,, 7 | ,, 12 |
| 1903 | June 8 | ,, 11 | ,, 12 | ,, 12 |
| 1904 | May 29 | ,, 1 | ,, 7 | ,, 8 |
| 1905 | June 6 | ,, 8 | ,, 9 | ,, 10 |
| 1906 | ,, 3 | ,, 6 | ,, 7 | ,, 8 |
| 1907 | May 31 | ,, 5 | ,, 11 | ,, 11 |
| 1908 | June 8 | ,, 10 | ,, 11 | ,, 11 |
| 1909 | ,, 1 | ,, 2 | ,, 3 | ,, 3 |
| 1910 | May 28 | ,, 2 | ,, 3 | ,, 3 |
| 1911 | June 1 | ,, 2 | ,, 4 | ,, 4 |
| 1912 | ,, 4 | ,, 6 | ,, 12 | ,, 12 |
| 1913 | May 24 | ,, 1 | ,, 6 | ,, 7 |
| 1914 | ,, 28 | ,, 5 | ,, 13 | ,, 13 |
| 1915 | June 3 | ,, 12 | ,, 17 | ,, 18 |
| 1916 | May 26 | May 27 | May 31 | ,, 1 |
| 1917 | ,, 26 | ,, 29 | June 4 | ,, 5 |
| 1918 | ,, 7 | ,, 15 | May 22 | May 25 |
| 1919 | ,, 16 | ,, 26 | June 4 | June 6 |
| 1920 | ,, 27 | June 2 | ,, 6 | ,, 6 |
| 1921 | June 1 | ,, 3 | ,, 10 | ,, 12 |
| 1922 | May 25 | May 31 | ,, 10 | ,, 12 |
| 1923 | June 4 | June 11 | ,, 12 | ,, 13 |
| 1924 | May 31 | ,, 3 | ,, 10 | ,, 12 |
| 1925 | ,, 27 | May 28 | May 29 | May 29 |
| 1926 | ,, 28 | June 5 | June 9 | June 10 |
| 1927 | ,, 23 | May 27 | ,, 10 | ,, 10 |
| 1928 | ,, 31 | ,, 31 | ,, 5 | ,, 7 |
| 1929 | ,, 29 | ,, 30 | ,, 1 | ,, 6 |
| 1930 | ,, 21 | June 7 | ,, 8 | ,, 9 |
| 1931 | ,, 23 | May 29 | ,, 14 | ,, 14 |
| 1932 | ,, 14 | June 2 | ,, 3 | ,, 3 |
| 1933 | ,, 22 | May 28 | ,, 1 | ,, 1 |
| 1934 | June 6 | June 6 | ,, 10 | ,, 10 |
| 1935 | ,, 10 | ,, 10 | ,, 12 | ,, 14 |
| 1936 | May 20 | May 22 | May 29 | ,, 1 |
| 1937 | June 3 | June 10 | June 11 | ,, 12 |
| 1938 | ,, 1 | ,, 2 | ,, 2 | ,, 4 |
| 1939 | ,, 6 | ,, 6 | ,, 7 | ,, 9 |
| 1940 | ,, 7 | ,, 13 | ,, 16 | ,, 18 |
| 1941 | May 23 | ,, 3 | ,, 14 | ,, 16 |
| 1942 | June 4 | ,, 8 | ,, 12 | ,, 13 |
| 1943 | May 12 | May 14 | May 21 | May 21 |

forward to the onset of the monsoon with great anxiety and prays for a timely and suitable distribution of rainfall during the season. The SW. monsoon has been described in various publications of the India Meteorological Department. Figs. 4 and 5 show the *normal* dates of *onset* and of *withdrawal* of this monsoon in different parts of India. The actual dates of onset as well as the intensity and distribution in time and

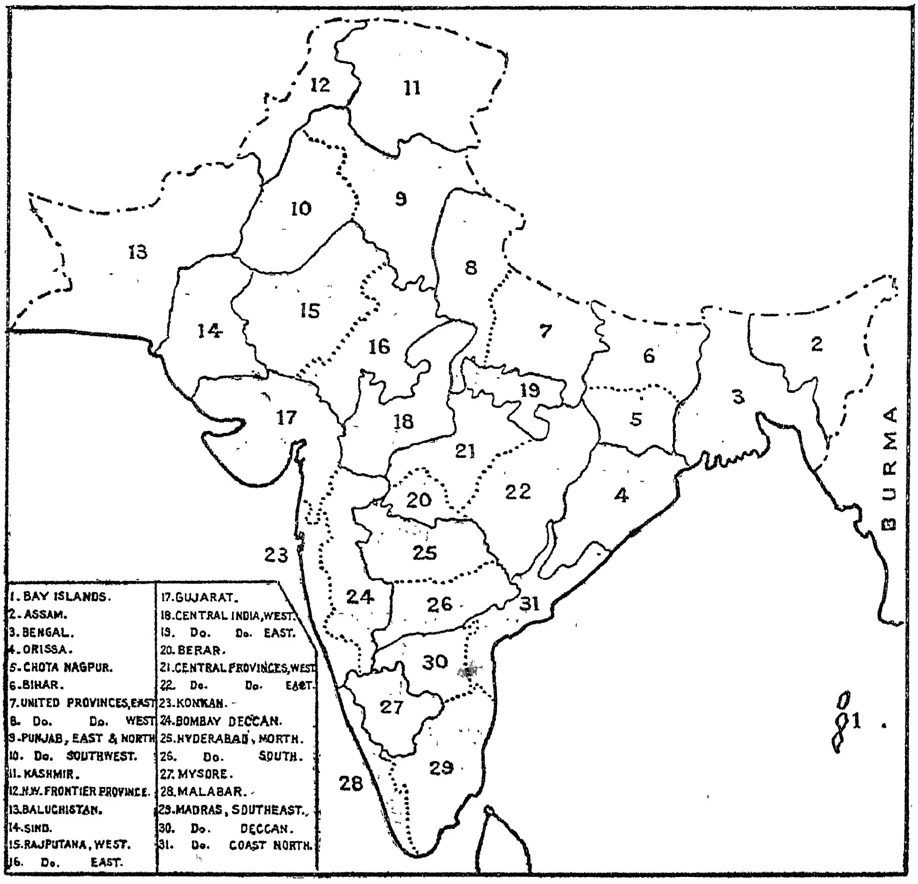



FIG. 3. Map of India showing the rainfall subdivisions.

space of the monsoon precipitation vary from year to year. Table 2 gives the actual dates of establishment of the SW. monsoon in four areas along the west coast of the peninsula. It will be noticed that there is a considerable variation not only in the *dates* of establishment but also in the speed with which the monsoon current moves from the Travancore–Cochin area in the south towards Kolaba in the north (near Bombay). Table 3 below summarizes the information given in Table 2.

As the major agricultural operations have to synchronize with the monsoon rains, the importance of predicting the date of establishment of the monsoon in different parts of the country, the spells of rain and breaks which occur during the season, cannot be over-emphasized.

(*b*) *Survey of the past 70 monsoons (1875–1944): Frequency of drought and flood years.*—For this purpose the total rainfall during the period June to September is considered. If the deviation of the actual rainfall in a year is more than about twice the mean deviation, that year is defined as a year of flood or drought according as the departure is positive or negative.

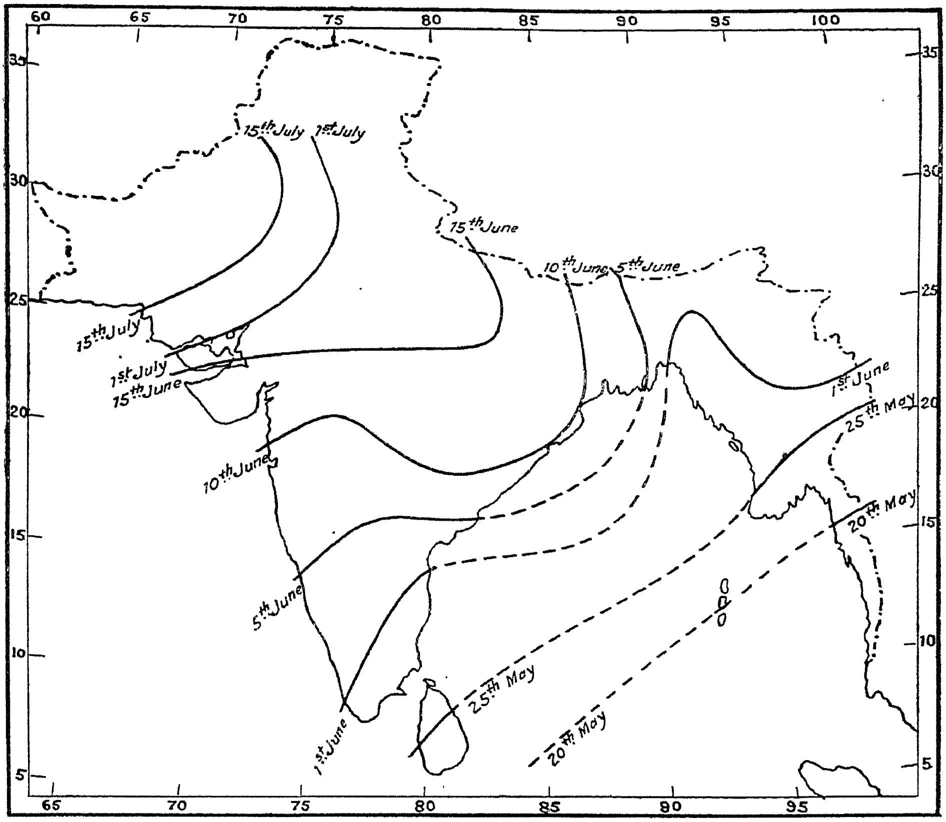



FIG. 4. Normal dates of onset of SW. Monsoon.

TABLE 3. *Dates of Establishment of the SW. Monsoon along the West Coast of India*

| *Area* | *Mean date* | *Standard deviation (in days)* | *Earliest date* | *Latest date* |
|---|---|---|---|---|
| Travancore–Cochin | May 29 | 7·0 | May 7 | June 10 |
| South-Kanara . | June 3 | 5·7 | ,, 15 | ,, 12 |
| Ratnagiri . . | ,, 7 | 5·4 | ,, 22 | ,, 19 |
| Kolaba . . | ,, 8 | 5·2 | ,, 25 | ,, 21 |

Fig. 6 shows at a glance how the monsoon has behaved in the past 70 years in each of the 30 rainfall subdivisions of India. In the figure the filled circle indicates a flood, the open circle a drought, and the

spaces which are blank are years and subdivisions with more or less normal monsoon rainfall. At the bottom of this diagram are given, for each subdivision, (1) the normal monsoon rainfall, (2) the mean deviation, (3) the limit for abnormality, i.e. the amount by which the actual rainfall should be in excess or defect if it is to be labelled as 'abnormal' (flood or drought, as the case may be), (4) the total number of floods during the period 1875 to 1944, (5) the total number of droughts during

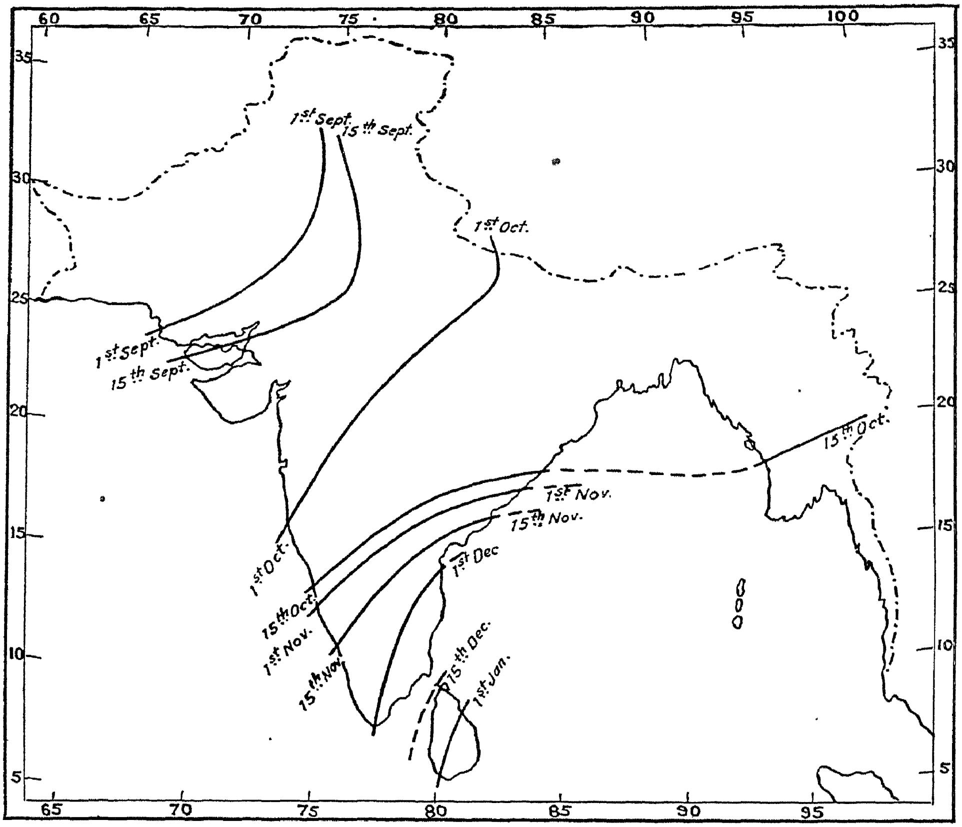



FIG. 5. Normal dates of withdrawal of SW. Monsoon.

the period 1875 to 1944, and (6) the total number of abnormal years (i.e. floods plus droughts) during the period 1875 to 1944.

These figures show that when we consider a sufficiently large number of years, the frequencies of floods and droughts tend to equalize; also, areas with a very low rainfall, e.g. Baluchistan, Sind, Rajputana, &c., are those where the total number of abnormalities is maximum; in areas like the Konkan, Malabar, Bengal, &c., where the monsoon rainfall is above 40 in., the frequency of abnormal years comes down very much.

It is still more interesting to study the distribution of floods and droughts in the various subdivisions in each year. The years 1877, 1899, and 1918 stand out very prominently as years of general drought. It will be recalled that these were actually years of great famine and

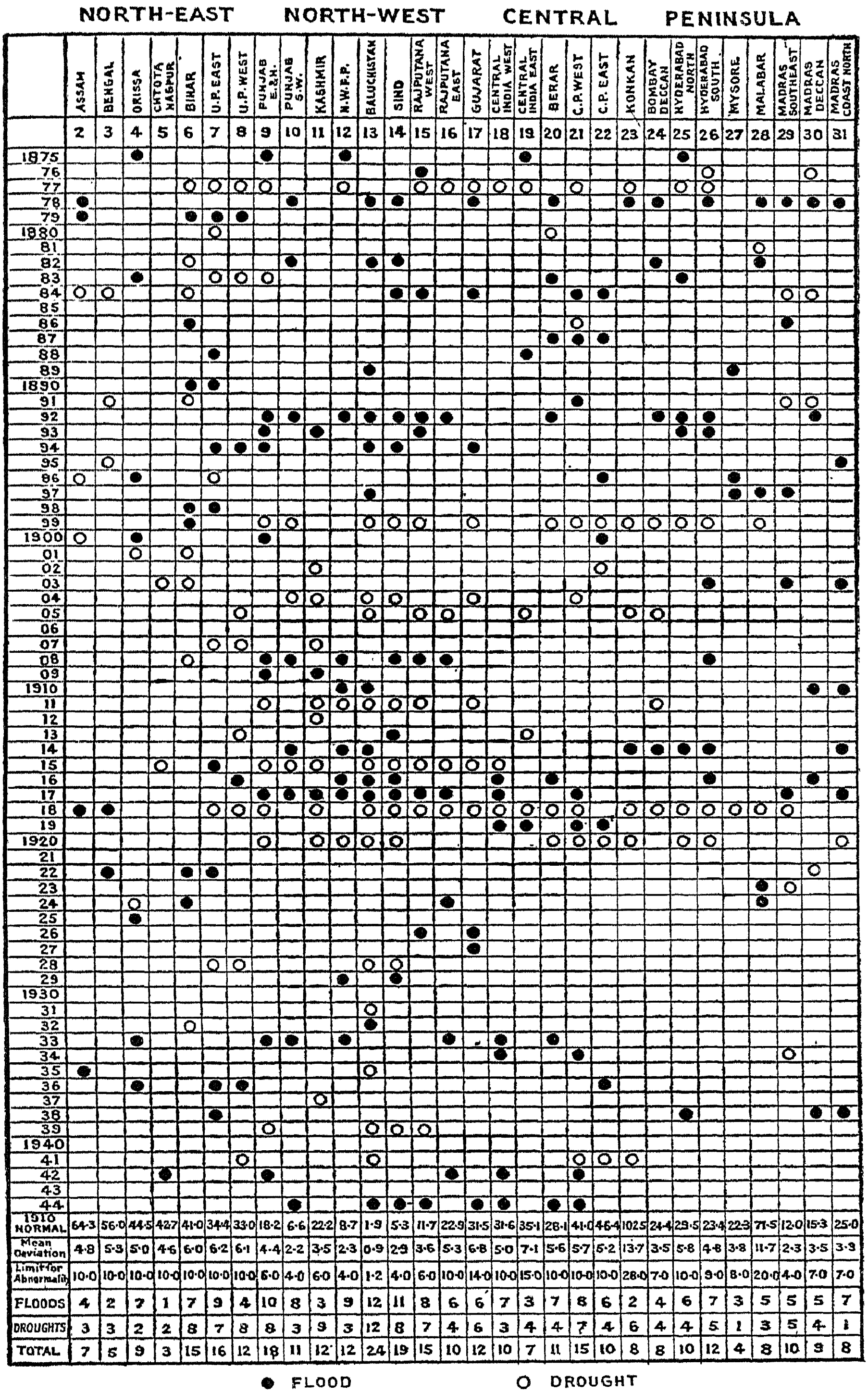



FIG. 6. Floods and droughts in India. Years of floods and droughts have for this purpose been defined as years with abnormality greater than twice the mean deviation.

distress. The year 1920 was one of partial drought, only the north-west and the central parts of the country being affected. The years of general flood are 1878, 1892, and 1917. In two instances at least (1877, 1878, and 1917, 1918) droughts and floods occurred in adjacent years, but there is usually no regularity in time in the distribution of droughts and floods. The chances of one drought year being succeeded by another or a flood year being succeeded by another in a particular subdivision

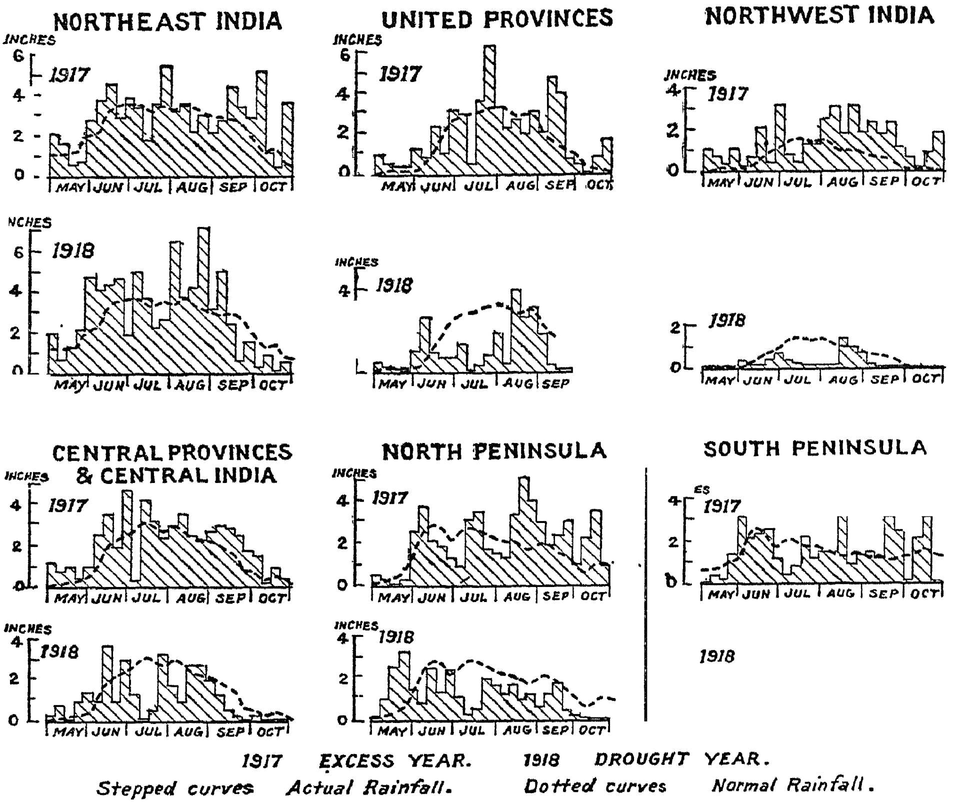



FIG. 7. Progress of the monsoon week by week.

appear to be small. Areas of drought and floods are, however, associated into centres of defective or excessive rainfall in the years in which they do occur. For the rest, the reader can judge for himself from Fig. 6 how liable India is to the incidence of abnormal monsoons.

Before leaving this topic it will be interesting to compare the actual distributions of *weekly* rainfall during the monsoon season of the years 1917 and 1918, as they are likely to show up the contrast, not only in the total rainfall, but also in the distribution thereof. Fig. 7 shows the rainfall distribution in 1917 and 1918, for each of the main divisions: (1) NE. India; (2) the United Provinces; (3) NW. India; (4) Central Provinces and Central India; (5) North Peninsula; (6) South Peninsula.

The dotted curves represent the normal weekly rainfall and the hatched area shows the actual rainfall. There is little contrast between

1917 and 1918 in NE. India as the rainfall was more or less normal in both the years. Over the other five divisions of the country, however, the contrast between the excess and the defect in 1917 and 1918 respectively was very marked.

### 4. *Contemporary Relationships of Monsoon Rainfall in Fifteen Divisions*

We have just seen that the monsoon rainfall varies from year to year both as regards the total rainfall as well as its distribution during the season. Administrators and others interested in the country as a whole may naturally inquire whether the effects of a deficiency in the monsoon rainfall in one part of the country is likely to be compensated by the effects of excess in some other part or parts.

Table 4 below expresses the relation between the monsoon rainfall in each of the 15 divisions and the remaining divisions in the form of contemporary correlation coefficients. A positive coefficient in the table indicates the two areas concerned are likely to be affected similarly (i.e. both may have heavy rains in some years and deficient rains in other years). A negative coefficient would indicate that a decrease in one is likely to be associated with an increase in the other area. Looking at the correlation coefficients in each row, one notices that a vigorous monsoon over Burma tends to be associated with a subnormal monsoon over India (and vice versa). To a smaller extent, excessive rainfall over NE. India tends to be associated with a defect elsewhere (and vice versa). Elsewhere, in India, i.e., NW. India, Central India, and the Peninsula, the correlation coefficients are generally positive, indicating that departures from normal are likely to be similar over the greater part of India, as indeed the dot-diagram (Fig. 6) does suggest in regard to even pronounced abnormalities like floods and droughts.

### 5. *Is India's Climate Changing? Are there Secular Variations or Periodicities in Indian Rainfall?*

The longest meteorological records in India are of rainfall at the cities of Madras (from 1813), Bombay (from 1847), and Calcutta (from 1829).

The rainfall data of the above stations as well as of shorter series in the case of some 10 stations in Bihar were examined for periodicity. In some cases there were significant periods, but considering that neighbouring stations do not indicate similar periods, not much importance can be attached to these results. It may be worth while to examine the question more extensively for a network of selected stations or selected areas in India, for settling this point conclusively. Evidence so far collected does not, however, support the possibility of any regular periodicity in Indian rainfall.

### 6. *Occasions of Unusually Heavy Rainfall*

The frequency of heavy rainfall over India has been discussed in a recent note by Doraiswamy and Mohamad Zafar (Scientific Notes, Ind.

Table 4. *Monsoon Rainfall, June to September. Inter-correlations between Pairs of Divisions. Period, 1875–1918*

(*Vide* Table E, Memoirs of the Ind. Met. Dept., Vol. **25**, Part ii, p. 23)

| *Division* | *II* | *III* | *IV* | *V* | *VI* | *VII* | *VIII* | *IX* | *X* | *XI* | *XII* | *XIII* | *XIV* | *XV* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I Burma | −0·47 | −0·14 | −0·05 | −0·01 | −0·09 | −0·21 | −0·29 | −0·07 | −0·26 | +0·01 | −0·01 | −0·32 | −0·15 | −0·33 |
| II Assam | .. | +0·45 | +0·27 | +0·01 | −0·16 | −0·10 | −0·13 | −0·17 | −0·24 | −0·27 | −0·40 | −0·01 | −0·11 | +0·14 |
| III Bengal | .. | .. | +0·56 | −0·07 | −0·07 | −0·05 | +0·04 | −0·24 | −0·31 | −0·22 | −0·45 | −0·18 | −0·15 | −0·12 |
| IV Bihar and Orissa | .. | .. | .. | +0·31 | +0·13 | +0·06 | +0·06 | +0·05 | −0·10 | +0·04 | −0·27 | −0·01 | −0·07 | −0·16 |
| V United Provinces | .. | .. | .. | .. | +0·49 | +0·31 | +0·06 | +0·55 | +0·30 | +0·68 | +0·33 | +0·37 | +0·07 | +0·22 |
| VI Punjab | .. | .. | .. | .. | .. | +0·82 | +0·56 | +0·87 | +0·59 | +0·79 | +0·59 | +0·61 | +0·11 | +0·35 |
| VII N.W.F.P. | .. | .. | .. | .. | .. | .. | +0·65 | +0·73 | +0·59 | +0·64 | +0·46 | +0·63 | +0·22 | +0·45 |
| VIII Sind | .. | .. | .. | .. | .. | .. | .. | +0·50 | +0·65 | +0·34 | +0·34 | +0·40 | +0·24 | +0·40 |
| IX Rajputana | .. | .. | .. | .. | .. | .. | .. | .. | +0·57 | +0·81 | +0·54 | +0·57 | +0·21 | +0·40 |
| X Bombay | .. | .. | .. | .. | .. | .. | .. | .. | .. | +0·46 | +0·58 | +0·72 | +0·53 | +0·66 |
| XI Central India | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | +0·61 | +0·40 | +0·05 | +0·21 |
| XII Central Provinces | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | +0·55 | +0·07 | +0·18 |
| XIII Hyderabad | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | +0·38 | +0·61 |
| XIV Mysore | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | +0·80 |
| XV Madras | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |

Met. Dept., Vol. 7, No. 77). With reference to the heaviest fall in a day, they find that:

(i) Falls exceeding 5 in. in 24 hours have occurred over the whole of India excluding NE. Baluchistan and parts of the NW. frontier.

(ii) Falls have not exceeded 10 in. in 24 hours over most of the interior of the Peninsula and of Burma and in a few districts in the Central parts of the country.

(iii) Falls of 15 to 20 in. in 24 hours have occurred all along the west coast including Gujerat and Kathiawar, on the south Coromandel coast, on the north Burma coast, in south Assam, in Bengal, and the foot of the Himalayas.

(iv) A few isolated falls of 20 in. and over have occurred in the plains.

(v) The greatest fall of over 40 in. in 24 hours has occurred at Cherapunji in the Khasi hills.

When heavy rainfall occurs consecutively on a number of days and particularly over the catchment areas of rivers, the magnitude of the ensuing floods may well be imagined. Ramkrishnan (Scientific Notes, Ind. Met. Dept., 7, No. 74) has estimated the total volume of water precipitated over certain areas in South India on days when they were under the grip of storms coming from the Bay of Bengal. The values given by him for one of these storms are quoted below:

| *Date* | *Area on land which had rain of 0·5 in. and more in sq. km.* | *Volume of water precipitated on land in cu. km.* |
|---|---|---|
| 21.10.30 | 60,150 | 1·9 |
| 22.10.30 | 53,730 | 1·6 |
| 23.10.30 | 71,540 | 4·9 |
| 24.10.30 | 103,660 | 8·0 |
| 25.10.30 | 133,740 | 6·5 |
| 26.10.30 | 141,620 | 7·1 |
| 27.10.30 | 342,520 | 11·9 |

Increasing forest-cover, checking erosion, delaying flood-peaks, and training the major rivers, &c., are problems which have begun to demand an increasing attention of the State.

## 7. *Regional Peculiarities in Distribution of Rainfall: Climatic Homogeneity*

Even if we divide the country into climatically homogeneous tracts, judging from the normal rainfall, there are still outstanding local peculiarities. This may be emphasized with the aid of a few examples.

Suppose that a weather forecaster expects a particular subdivision in the country to come under the influence of disturbed weather and forecasts rainfall over the area. Can he expect all the rain-gauge stations to record more or less similar rainfall during a particular day? Or will the rainfall be very variable? This involves the question of rainfall variability in space and is very important from the weather forecaster's point of view.

We may also consider the point of view of an irrigation engineer faced by the problem of constructing reservoirs to serve the agriculturist's needs. Should he construct one big reservoir at a likely place or should he scatter a series of small reservoirs, casting his net wide as it were, so that one or the other of the reservoirs collects such rain as may fall over its neighbourhood? How would the variability between stations in a given area compare with the variability between days of a month and with that due to random chance?

In connexion with a recent inquiry, the variability of rainfall in the month of July 1942 was analysed for a number of representative areas in India, taking 20 stations selected at random from each of these areas. Table 5 gives the analysis of variance between 'stations', 'days' of the month, and 'residual' (due to random variability), for the Punjab, the United Provinces, the Central Provinces, Bengal, Rajputana, and

TABLE 5. *Analysis of Variance of Rainfall in July 1942*

| *Due to* | *Degrees of freedom* | *Sum of squares* | *Mean square (variance)* | *Standard deviation* | *Variance ratio: 'F'* | *Rainfall per day* | *Coefficient of variability (%)* |
|---|---|---|---|---|---|---|---|
| 1. *The Punjab.* | | | | | | | |
| Stations | 19 | 21·1334 | 1·1123 | 1·55 | 3·73* | 0·228 in. | 680 |
| Days | 30 | 19·8421 | 0·6614 | 0·81 | 2·22* | .. | 356 |
| Residue | 570 | 169·8981 | 0·2981 | 0.55 | .. | .. | 241 |
| Total | 619 | 210·8736 | 0·3407 | .. | .. | .. | .. |
| 2. *The United Provinces* | | | | | | | |
| Stations | 19 | 16·1105 | 0·8479 | 0·92 | 1·55 | 0·466 in. | 197 |
| Days | 30 | 114·5280 | 3·8143 | 1·95 | 6·97* | .. | 418 |
| Residue | 570 | 312·1042 | 0·5475 | 0·74 | .. | .. | 159 |
| Total | 619 | 442·7427 | .. | .. | .. | .. | .. |
| 3. *The Central Provinces* | | | | | | | |
| Stations | 19 | 45·5754 | 2·3987 | 1·55 | 1·35 | 0·697 in. | 222 |
| Days | 30 | 270·4394 | 9·1465 | 3·02 | 5·16* | .. | 433 |
| Residue | 570 | 613·9953 | 1·7715 | 1·33 | .. | .. | 191 |
| Total | 619 | 929·9901 | 1·5024 | .. | .. | .. | .. |
| 4. *Bengal* | | | | | | | |
| Stations | 19 | 41·4545 | 2·1818 | 1·48 | 3·62* | 0·422 in. | 350 |
| Days | 30 | 43·2902 | 1·4430 | 1·20 | 2·39* | .. | 284 |
| Residue | 570 | 343·4197 | 0·6025 | 0·78 | .. | .. | 185 |
| Total | 619 | 428·1644 | 0·6917 | .. | .. | .. | .. |
| 5. *Rajputana* | | | | | | | |
| Stations | 19 | 108·8973 | 5·7314 | 2·39 | 6·92* | 0·417 in. | 573 |
| Days | 30 | 46·2551 | 1·5418 | 1·24 | 1·86 | .. | 297 |
| Residue | 570 | 471·9398 | 0·8280 | 0·91 | .. | .. | 218 |
| Total | 619 | 627·0922 | 1·0131 | .. | .. | .. | .. |
| 6. *Malabar* | | | | | | | |
| Stations | 19 | 85·4648 | 4·4981 | 2·12 | 5·53* | 1·331 in. | 159 |
| Days | 30 | 382·1749 | 12·7392 | 3·57 | 15·68* | .. | 268 |
| Residue | 570 | 463·1872 | 0·8126 | 0·90 | .. | .. | 68 |
| Total | 619 | 930·8269 | 1·5038 | .. | .. | .. | .. |

* Means significant at 1 per cent. level.

Malabar. Column (5) gives the standard deviation of the variability 'between stations', 'between days', and 'residual' or error. The next column gives the ratios of the variances, i.e.

$$\frac{\text{Variance between stations}}{\text{residual variance}} \text{ and } \frac{\text{Variance between days}}{\text{residual variance}}.$$

If the variability 'between stations', 'between days', and 'residual' are all of the same order of magnitude the ratio $F$ will not be significant.

In the Punjab, Bengal, and in particular Rajputana and Malabar, the variability between stations is very significantly larger than that caused by random chance. In Malabar this variability is due to orography, whilst in Rajputana it represents a real climatic non-homogeneity. The variability between days is significant in all cases. In places like Rajputana it is indeed difficult to indicate where exactly rain would fall during a wet spell. The engineer would be well advised to construct a wide network of tanks in preference to a single big tank in such tracts.

### 8. *Irrigation Works and Large-scale Reservoirs, Bunds, &c.*

Wherever the precipitation falling over a very wide catchment is drained into large river-systems like the Indus and Ganges, it is obvious that irrigation projects will be successful, as has indeed happened in the Punjab and Sind. In the United Provinces, besides canal irrigation, tube-wells are also being sunk on a large scale.

It may be pointed out that the large dry tracts of Peninsular India which are not fed by rivers can get adequate supplies of water for agriculture if the necessary irrigation-projects are set up at suitable localities in the catchment areas of the Western Ghats *which receive sufficient rains for this purpose even in years with weak monsoons.* Much of this water is now drained by rapids flowing into the Arabian Sea. If large reservoirs are built up on the Ghats over elevated areas, taking advantage of natural facilities for impounding the rain-water, the water so collected can be fed into the plains to the east of the Ghats through canal systems. This is a problem which the State alone can tackle; it is full of large potentiality for the future of the arid tracts of Peninsular India.

9. In concluding this all too brief a summary of India's rainfall as affecting its agricultural potentialities, it may be appropriate to state that the India Meteorological Department is undertaking, in the very near future, to broadcast special weather bulletins and forecasts for the farmer. Seven Regional Forecasting Centres have been started. These will cater for the special weather requirements of their respective regions. Warnings for heavy and untimely rainfall, heat waves, cold waves, droughts, hail-storms, high winds, etc. will be issued, keeping in view the needs of the important crops of each region. In this new undertaking the Agricultural Meteorologist will maintain a close liaison between agriculture and meteorology.

(*Received September 3, 1945*)

# MEMOIRS

OF THE

# GEOLOGICAL SURVEY OF INDIA

VOLUME 81

# THE STRUCTURAL AND TECTONIC HISTORY OF INDIA

BY

M. S. KRISHNAN, PH.D., F.N.I.

*Published by order of the Government of India*

CALCUTTA: SOLD AT THE CENTRAL BOOK DEPÔT, 8, HASTINGS STREET, AND AT THE OFFICE OF THE GEOLOGICAL SURVEY OF INDIA, 27, CHOWRINGHEE ROAD
DELHI: SOLD AT THE OFFICE OF THE MANAGER OF PUBLICATIONS
EUROPE & AMERICA: SOLD AT THE OFFICE OF THE HIGH COMMISSIONER FOR INDIA, INDIA HOUSE, ALDWYCH, LONDON, W.C. 2.

PRINTED BY THE GOVERNMENT OF INDIA PRESS, CALCUTTA, INDIA,
1953.

*Price Rs. 2 As. 6 or 4 sh.*

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1953.

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# GEOLOGICAL SURVEY OF INDIA

## THE STRUCTURAL AND TECTONIC HISTORY OF INDIA.*

By M. S. Krishnan, Ph.D., F.N.I.,

*Director, Geological Survey of India (with Plates 1 to 4).*

## INTRODUCTION

For geological studies, India (for the sake of brevity, 'India' is used here to include India and Pakistan) is appropriately divided into two units, one being peninsular India and the other the mountain girdle of the Himalayan, the Baluchistan and Burmese arcs. The two are separated by a deep, alluvium-filled depression through which the Indus, Ganges and Brahmaputra rivers flow on the Peninsular side of the mountains. The above statement requires a little modification in that the edges of the peninsular mass are found to extend well into the region of the Lesser Himalayas (*i.e.*, between the foot-hills and the central range of high peaks) where they are inextricably mixed with the rocks of the extra-Peninsular regions.

The Peninsula is a stable mass of Archaean and Pre-Cambrian formations which are exposed over more than half its area. The rest is occupied by Gondwana and later sediments and by the lava flows of the Deccan Trap formation. The major mountain building disturbances ceased in Pre-Vindhyan (Pre-Cambrian) times. Some minor folding, block faulting (possibly block uplift and down-faulting) and epeirogenic movements have affected it in post-Cambrian epochs. Block faulting has been responsible for the preservation of India's chief coalfields, while epeirogenic movements are attested by the marine transgressions and regressions which have left their marks in the coastal regions.

The mountainous extra-Peninsular area, on the other hand, has been subjected to stupendous mountain building activity in the Cretaceous, Tertiary and Pleistocene times. It shows a complete succession of sedimentary rocks of all ages from the Cambrian to the Pleistocene,

* This is a revised and enlarged version of a short paper entitled "The Structure of India" published in the *Indian Geographical Journal* (Madras), Vol. XVIII, No. 4, pp. 137-155, 1943.

deposited in a great basin of geosynclinal dimensions bordering India on the north. This region is perhaps best described as the meeting ground of two continental masses—India from the south and Asia from the north. The cores of the uplifted mountains show large scale intrusions of plutonic rocks, mainly of granitic composition, but also some basic and ultrabasic rocks in places. Only parts of the mountainous area have been mapped and there remain large gaps to be filled up. The mountain belts are characterised by complex folding, overthrusts and 'nappes' of great dimensions, involving horizontal compression of the crust of several hundred miles. Each of the three major arcs making up this region has its convex side facing the stable mass of the Peninsula, so that the thrusts are directed towards the south in the Himalayas, towards the east in the Baluchistan arc and towards the west in the Burmese arc. Each of these arcs consists of a succession of mountain ranges one behind the other and, in a few places, they are gathered up by the underlying wedges of the Peninsular mass into a series of festoons, so conspicuously seen in the Baluchistan arc. Intrusive plutonic rocks are present in all the arcs but the details about their distribution are still wanting as there are several areas, especially in the Himalayas and in the mountains of the Assam-Burma border, about which geological information is scanty or entirely lacking.

As the stratigraphic and tectonic histories of the two regions are different, it would be best to treat them separately until the Tertiary, when they encroached on and influenced each other.

# 1. The Archaean Formations

More than half the area of the Peninsula exposes Archaean gneisses and schists and Pre-Cambrian sediments and igneous rocks which have been metamorphosed to various degrees. The earlier rocks were probably largely of igneous origin, penetrated intimately by granitic intrusives, giving rise to banded and composite gneisses. The original volcanic flows and tuffs and sedimentary rocks have been converted into amphibolites and various types of schists. Three periods of granitic intrusion have been recognised and it is not unlikely that more will come to light when more detailed studies are undertaken in different regions. The earliest of these is generally a highly folded gneissic complex for which the term 'Peninsular Gneiss' has been used in South India (Smeeth, 1916). The next appears to be a porphyritic or augen gneiss (in the Central Provinces), while the third is a granite which is to a large extent unaffected by folding and is of Upper Pre-Cambrian age—the Closepet granite of Mysore, the Arcot and Hosur granite of Madras, the Erinpura granite of Rajputana, the Singhbhum granite of Bihar, etc.

The highly metamorphosed and schistose Pre-Cambrians are known by different names in different parts of the country — the Dharwars in South India, Champaners and Aravallis in Gujarat and Rajputana, the Sausars and Sakolis in the Central Provinces, Shillong series in Assam, Bengal gneiss in Bihar, Darjeeling and Daling series in Sikkim, and so on.

The earlier gneisses are intruded by the charnockites (hypersthene granulites) which are well developed, especially all along the Eastern Ghats up to the Nilgiri mountains and along the Western Ghats from Coorg to the southern tip of the Peninsula. They are pre-granite in age and presumably pre-Cuddapah (pre-Algonkian) as they show evidence of having been folded, in many places. They generally exhibit the characteristics of igneous intrusives as pointed out by T. H. Holland (1900) and are associated with pegmatitic phases. The larger masses are acid to intermediate in composition, but in certain areas there are ultrabasic members composed mostly or entirely of enstatite-hypersthene. In the Eastern Ghats of Jeypore in Orissa, they show evidences of later albitisation (Crookshank, 1938). Gneissic banding and folding are common in the major exposures of the Eastern Ghats, Palni and Nilgiri hills, etc. The charnockites are now generally considered to be an igneous suite which has been subjected to high-grade plutonic metamorphism, with the development of hypersthene which is their most characteristic femic mineral. Augite (often titaniferous) and garnet are commonly found, while minerals with hydroxyl molecules like amphibole are comparatively rare and often absent. The distinctly bluish colour of the quartz (and even of the feldspar) is generally attributed to the presence of minute rod-like inclusions of rutile, but may really be due to some other cause. Whatever their origin, whether entirely igneous or derived from a variety of pre-existing rocks as held by

Vredenburg (1918) and B. Rama Rao (1945), it is clear that they have undergone severe metamorphism under conditions of the kata-zone. The recent discovery of workable chromite deposits in such rocks in the Kondapalle Hills near Bezwada in the Kistna Valley gives rise to the speculation that they may consist, in part, of material which may have risen up from the peridotite shell of the earth, especially as the charnockites appear to be associated with folded mountain belt of the Eastern Ghats. The charnockite areas have not been studied in sufficient detail for us to be able to say whether the ultrabasic members are intrusive into the intermediate and acid members or whether they are merely differentiates from a common magma.

## 2. Trend Lines in the Archaeans

There are certain persistent regional trends noticeable in the Archaean

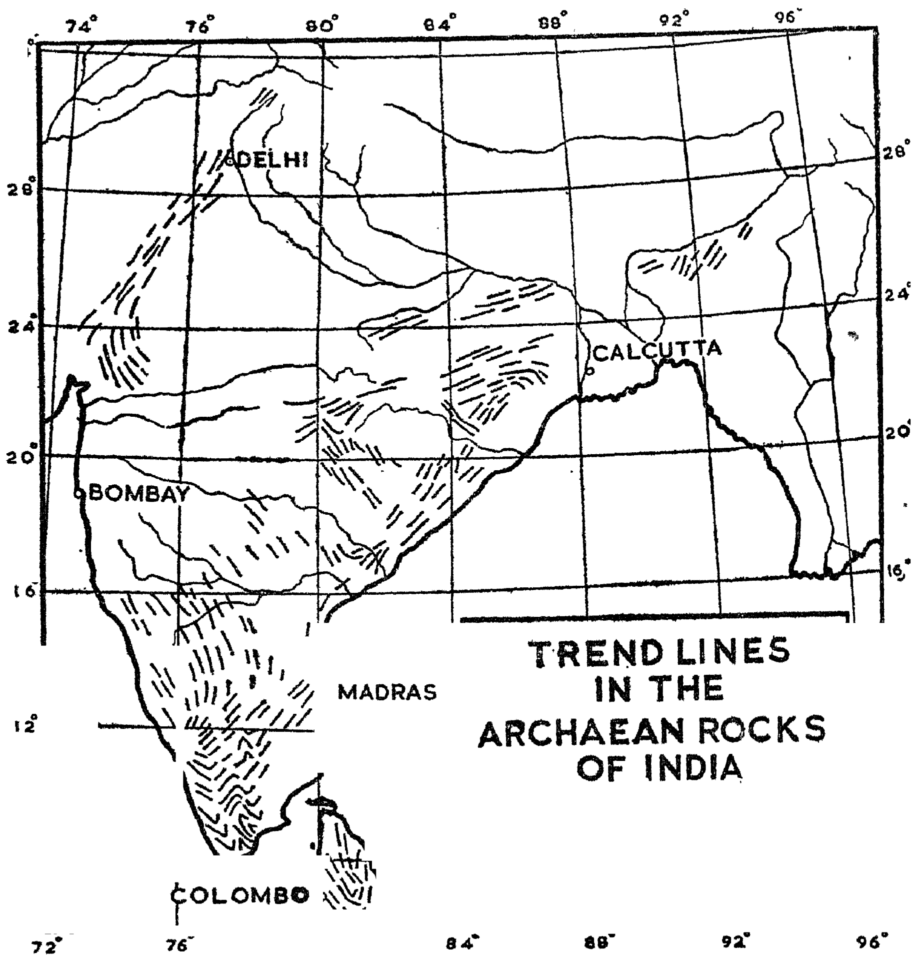



Fig. 1.

rocks of the different parts of India, which are described below (see also Fig. 1).

*The Aravalli strike.*—The Aravalli mountain belt of Rajputana is characterised by a N.E.-S.W. strike which can be seen from Delhi to Champaner in Gujarat at the head of the Gulf of Cambay. In the Gujarat region it tends to splay out rather widely and a part of it, if continued, is directed towards Mysore in South India where the Dharwarian rocks have a dominant N.N.W.-S.S.E. strike. Though the area intervening between Gujarat and Mysore is covered by the Deccan Trap lavas, there appears to be little doubt about the direct connection between the Archaeans of the two areas. Still further east in Gujarat, the Aravalli trend seems to turn south-east and east. In the absence of detailed studies in this critical region, it is not possible to say whether the Aravalli trend gradually turns round and merges into the Satpura strike (see below) or whether the apparent turning is merely due to the interaction between two independent trends, one superimposed on the other.

The Aravalli strike is found to continue into Garhwal in some of the older rocks (Auden, 1933, p. 467). It may be that there was a rejuvenation of the northern part of the Aravallis in Tertiary or post-Tertiary times, but on this point there is no clear evidence. However, the rocks referred to above have retained their original strike unaffected by the Tertiary orogenic movements, probably because the movements were parallel to this strike direction. Detailed studies of the post-Archaean formations in this region will bring to light facts which will explain their distribution in relation to the Aravallis (Fermor, 1930, p. 391).

The Aravalli-Champaner trend apparently continues to the south into the Laccadives through the Banks in the Gulf of Cambay and the Direction and Angria Banks further south. The Laccadive, Maldive and Chagos island groups lie along this alignment and all of them rise up from platforms 1,800 to 2,000 fathoms deep, as pointed out by Sewell (1935) who quotes the opinion of Moresby who surveyed this region in 1834 to 1836. G. Schott (1902, p. 117) was also of the opinion that the Maldives and the Chagos groups stand on parts of a single platform at the bottom of the sea. There is a breach in the continuity of the Aravallis in the Cambay-Gujarat region where transverse faults have let down a portion, probably in Upper Carboniferous times, while the western coast of India was faulted down in the Miocene. Little is known regarding the subsurface geology of the abovementioned island groups but their tops are built up of coral reefs which continue to grow at the present day. If the southward extension of the Aravallis into these island groups is accepted, their length in the submerged portion to the south of Champaner would amount to about 1,500 miles.

*The Dharwarian strike.*—As mentioned above, a part of the Aravallis in Gujarat trends in a SSE direction and apparently continues under the Deccan Traps into Mysore and adjacent parts of Hyderabad and Madras where the general trend is NNW-SSE to NW-SE. In the south of Mysore, near Mysore City and further south, the same rocks exhibit a high degree of metamorphism and assume a N-S strike, and finally

turn SW and WSW, thus adjusting their trend to that of the Eastern Ghats of Salem and the Nilgiris.

Wadia (1943) has identified three peneplanes—post-Archaean, post-Jurassic and Tertiary—in Ceylon which is geologically a part of Southern India. He believes (1942) that this holds for South India also where the charnockite massifs stand out, bounded by steep scarps, above the general level of the Mysore plateau and other hills to the south. Lower down are the general plains which grade into the coastal regions. The Nilgiri mountains are regarded by him as elevated to their present height by a Tertiary uplift.

In the region south and south-east of the Nilgiris the dominant strike is NW-SE, which continues into the south-western part of Ceylon. There is a great similarity between this (southernmost) part of South India, Ceylon and Madagascar in the rocks they contain and in the associated minerals—garnet, sillimanite, graphite, monazite, thorianite, ilmenite, zircon, etc.—so that the belief that they were all originally parts of a single land mass is greatly strengthened. There is indisputable evidence that Ceylon was connected to India until the Miocene and occasionally thereafter. The NW-SE strike of the southernmost part of India may or may not be part of the Dharwarian strike and a satisfactory decision of this question must await detailed structural studies of critical areas here.

*The Eastern Ghats strike.*—Parts of the Nilgiris and of the districts of Coimbatore and Salem to their east and north-east, exhibit an ENE-WSW strike. In South Malabar to the west of Nilgiris, NNW-SSE and N-S strikes are seen but some feldspathic schists further west show, according to Lake (1890, p. 12), an E-W strike of foliation. This latter foliation generally bends round the rocks which show the N-S strike. The feldspathic schists and their foliation therefore appear to be younger than the 'quartzose gneisses' having the Dharwarian strike (Oldham, 1893, pp. 36-37). This E-W strike may possibly be the westerly continuation of the ENE strike of the Nilgiris and may have a bearing on the presence of the Palghat gap—a conspicuous gap in the Western Ghats just south-west of the Nilgiri mountains.

Eastward of Wainad (the tract adjoining the Nilgiris on their north-west) and the Nilgiris, the ENE-WSW strike continues for some distance, but gradually assumes a NE-SW to NNE-SSW strike which is well seen in parts of Salem and Trichinopoly. It continues towards Madras City north of which it assumes a broad sigmoidal flexure parallel to the eastern margin of the Cuddapah basin and to the Madras coast. The southern part of this margin is in fact parallel to the trend of the Dharwarian schistose rocks into which the Nellore mica-pegmatites are intrusive. From Guntur and the Kistna Valley, the strike assumes a NE direction, but curves inwards with a NNE direction near the northern border of Orissa where it is either interfered with by the Satpura strike of the Gangpur-Singhbhum region or is obscured by alluvial cover. The western part of the wide belt in northern Orissa includes the iron-

ore ranges of Keonjhar and Bonai whose dominant trend is NNE-SSW. It is not unlikely that there is a bifurcation of the Eastern Ghats belt near Bezwada in north-eastern Madras[1], one part going straight south to Ceylon and the other continuing for some distance southwards and then bending round to the south-west to proceed to the Nilgiris through Arcot and Salem.

The effect of the Eastern Ghats orogeny is seen all along the eastern margin of the Cuddapah basin in Nellore and Guntur and almost up to the Singareni coalfield in Hyderabad. The eastern margin of the Cuddapah basin shows crushing and overthrusting. Some rocks near the Singareni coalfield show folding and high grade metamorphism whereby schists with garnet, kyanite, staurolite, etc., have been produced from the argillaceous members, and crystalline limestones and calciphyres from the calcareous ones. Granitic rocks are associated with the folding. Heron (1949, pp. 118-121) correlates these rocks with the 'Pakhals' which are considered to be the equivalents of the Cuddapahs (Algonkian). Mahadevan (1949), however, believes that the relationships, structure and metamorphism of these rocks, as well of the Kaladgis of southern Bombay, indicate an earlier age, *i.e.*, Archaean, for them. He points out that though the eastern margin of the Cuddapah basin of Madras shows evidence of folding and shearing, there are no associated granitic intrusives as in the case of the 'Pakhals' of the Singareni area. The elucidation of this problem would therefore have to await the results of detailed studies of critical areas in the Nellore-Guntur-Singareni region.

Holmes (1950, p. 26) has recorded the ages calculated for samarskite obtained from the pegmatites of Nellore, which are 830, 1550, 1760 million years, on data furnished by two groups of investigators in India. The first of these is not far out from the results given by minerals from post-Delhi pegmatites of Rajputana or from the post-Satpura pegmatites of Gaya in Bihar. The other two give much higher figures, 1550—1760 million years which must indicate an Archaean (Dharwarian) age. If the results are all reliable, one would be led to conclude that there must be two sets of pegmatites here, of vastly different ages. So far as I could gather, the samarskite came from undisturbed pegmatites of the Sankara and Parlapalle mines in the Gudur area which should be assigned a post-Dharwarian and pre-Cuddapah age. It will be necessary to repeat the chemical work on carefully selected material, as there is no field evidence, to the best of my knowledge, for the existence of two sets of pegmatites separated by such a large interval of time as the above results suggest.

The Eastern Ghats consist largely of charnockites and khondalites (garnet-sillimanite gneisses and schists) with some calc-rocks and metamorphosed manganiferous sediments. Fermor is of the opinion that they constitute a belt of block uplift and that the margins are zones of faulting.

[1] Dr. C. Mahadevan (personal communicaton) says that the bifurcation starts in the Kondapalle Hills, a few miles north-west of Bezwada.

Though, according to Crookshank (1938, pp. 399-404), no fault is discernible in the Jeypore region, Fermor's view is based on the high grade metamorphism characterising all the rocks of this belt which must have been acquired when the rocks were buried deep. Practically throughout the Eastern Ghats belt from Orissa to the Nilgiris, charnockites are conspicuously present and granitic intrusives are not wanting though they do not attain great importance.

*The Mahanadi Strike.*—In the area of Archaean rocks lying to the north-west of the Eastern Ghats, from the Godavari Valley to the Mahanadi Valley, the general direction of strike is NW-SE, but geological information on this region is still very poor. It will be noticed that this structural trend has controlled the formation of the block faults (' graben ') in which the Gondwana formations have been preserved in the Godavari and Mahanadi Valleys. As this trend is not very different from the Dharwarian, it is not clear whether this region is to be treated as a separate entity or as part of the Dharwarian structural province.

*The Satpura Strike.*—The last major trend is that of the Satpura Range with an ENE-WSW direction. The Satpura Range between the Narbada and the Tapti in Gujarat is made up of Deccan Traps and the trend is continued through the Mahadeva Hills, the Maikal Range, the Mainpat Hills and the north of the Chota Nagpur plateau to the Rajmahal region in the Ganges Valley. The Archaeans are seen mainly from Jubbulpore eastwards. There is also a southern group of conspicuous outcrops in the Nagpur-Chhindwara-Bhandara-Balaghat region of the Central Provinces and the Gangpur-Singhbhum region of Chota Nagpur, where the same strike is seen. Further east beyond the Rajmahal region which flanks the Ganges Valley, this trend is continued into the Garo Hills in the western part of the Shillong plateau, while much of the rest of the plateau shows the Eastern Ghats trend.

In Singhbhum in South Bihar, which has been mapped in recent years in detail by Dunn and others (1929, 1939, 1942), evidences of the Satpura orogeny have been studied. A major thrust zone separates the highly metamorphosed northern area from the unmetamorphosed southern area. This thrust zone runs roughly ENE-WSW and E-W for nearly 100 miles turning to the S-E near the eastern end and is associated with copper mineralisation because of which it is known as the ' Singhbhum Copper Belt '. There are two nearly parallel thrust zones to its north, one marking the northern border of a belt of lavas (Dalma Traps) and the other further north. All the three are parallel to the Satpura trend and tend to converge near Goilkera, west of Chakradharpur. The thrust in all cases is from the north. To the south of the main thrust zone, the same series of rocks are practically unmetamorphosed but have been affected by the folding of the Eastern Ghats (NNE) strike. The thrust

zone is continued westwards into Gangpur through the northern border of the Gangpur anticlinorium which contains rocks thought to be older than those of Singhbhum (Krishnan, 1937).

Beyond the last thrust zone in the north, there are granite gneisses which occupy a broad belt between south and north Bihar. They become conspicuously banded and gneissic as they approach the schists in the south and are granitic in the north. During the period of (Satpura) folding, ultrabasic rocks and granite were intruded the latter being apparently the younger. A phase of the granitic intrusion consists of granophyre and soda granite chiefly intruded along the main thrust zone, the copper mineralisation along the same zone being attributed to this phase.

## 3. Relative Ages of the Orogenic Cycles

Attention may be drawn here to the fact that the Aravalli trend of Rajputana is parallel to that of the Eastern Ghats ; the Dharwarian and Mahanadi trends (including that of the southernmost part of the Peninsula) may really be identical. There are areas in which the different trends meet each other. Structural and petrofabric studies in such areas must yield results of much value, for instance in eastern Gujarat, the Nilgiris and Malabar, Salem-Mysore and the western margin of the Eastern Ghats. In Bhandara in the Central Provinces and in southern Gangpur in Orissa there is evidence that three different trends come together forming triangular patterns.

There are few reliable data regarding the relative ages of the major folding movements which produced the trends described above. In the Aravalli region the diastrophism was repeated in Upper Pre-Cambrian (post-Delhi) times and acid lavas, granites and pegmatites were erupted and injected at the time of the later activity also. There is some evidence in the Gangpur anticlinorium that the Satpura trend has effected an older one, presumably the Eastern Ghats trend (Krishnan, 1937, p. 73). Because of this the porphyroblasts in certain mica schists have been only partially turned and the rocks have been subjected to regressive metamorphism.

A. Holmes (1949 and 1950) has investigated the ages of uraninite from a pegmatite from Gaya in the Satpura belt of Bihar and of uraninite and monazite from post-Delhi pegmatites of the Aravalli belt in Rajputana, and found that the former indicated an age of $955 \pm 40$ million years and the latter 735 million years. From these data he has deduced that the post-Delhi orogeny, with which the Rajputana pegmatite is associated, is younger than the Satpura orogeny which gave rise to the Gaya pegmatite. Since the Aravalli orogeny is much older than the

Delhi one, the former was thought to be the oldest of the Archaean orogenic cycles in India. The Eastern Ghats cycle was given an age intermediate between the Aravalli-Dharwar cycle on the one hand and the Satpura cycle on the other. Holmes has consequently formulated a succession of diastrophic cycles as shown below (1950, p. 27) :—

VINDHYAN

735 m. y.

DELHI CYCLE (= ? CUDDAPAH)

955 $\pm$ 40 m.y.

SATPURA CYCLE

EASTERN GHATS CYCLE

(ARAVALLI CYCLE) ?=DHARWAR CYCLE

OLDER GNEISSIC COMPLEX (= ? BUNDELKHAND GNEISS)

In explanation Holmes wrote (1950, p. 26) :—

"For this reason it is provisionally supposed that the Aravallis and the Dharwars constitute parts of a single orogenic belt. This is an example of a tentative correlation that remains to be proved by the dating of radioactive minerals. It should be added that the Aravallis are underlain by a " Gneissic Complex " which represents a still older orogenic belt.

The relative positions of the Satpura and Dharwar rocks can be arrived at by another route. The map shows that the Eastern Ghats belt, celebrated for its khondalites, kodurites and charnockites, cuts across the Dharwar belt and therefore represents a younger orogenic cycle. The Satpura belt, however, appears to be younger still, judging from observations made in Orissa by Krishnan (1943 a, p. 141). Minerals suitable for dating the late pegmatites of the Eastern Ghats belt (more likely to belong to the Dharwar belt) occur in the pegmatites of the Nellore district, and already a few analyses of samarskite have been made for the purpose. The crude ages so far available are 830, 1550, and 1760 m.y. On balance, these also suggest that the Eastern Ghats belt is older than the Satpura belt........"

In regard to the necessity for separating the different orogenic cycles in the Archaeans, Holmes wrote (1949, p. 299) :—

> "At the moment, however, it can be concluded either that the Satpura and Eastern Ghats belts are of about the same age, or that the Eastern Ghats belt is older than the Satpura belt. The tectonic evidence strongly supports the second view. In either case, the Dharwars are older than both. Rocks of the Eastern Ghats and Satpura belts should therefore no longer be referred to as 'Dharwars' as they commonly have been in the past (Krishnan 1935; Fermor 1936, p. 214) To do so would be to perpetuate a mistake that is analogous to the misuse of the term 'Laurentian' in North America. The original Laurentian rocks of the Grenville Province have a closing age of just over 1000 m.y. (Holmes 1948 a, 180-184). The post Keewatin pegmatites of the Rainy Lake may have an age of nearly 2000 m.y. (Holmes 1948 a, 189-193). Yet the post-Keewatin granites and migmatites have been called 'Laurentian', implying an entirely unjustified correlation with rocks 800 miles away and completely unconnected. Similar mistakes have been made in all the better known Pre-Cambrian shields, and only now, with the progress of mapping and the aid of radioactive minerals is it becoming possible to disentangle the long succession of orogenic belts which make up the so-called 'Archaean' once thought to represent an era of world-wide orogenesis."

In a discussion of the data presented by Holmes, Fermor (1950) remarks that the only conclusion to be drawn from them is that the pegmatites from which the uraninite and monazite were got had an age between 700 to 900 million years and that they cannot be used as indications of the ages of the schistose rocks cut through by these pegmatites, since these schistose rocks may be many millions of years older than the pegmatites, and since the pegmatites in the same area may be of more than one age.

In reply to Fermor's criticism, Holmes has pointed out that he was attempting to date the close of the orogenic periods while Fermor was thinking of the ages of the formations in the different belts (Holmes 1950 a, p. 227).

While discussing the different tectonic trends, I have pointed out that there is some evidence of the Satpura trend in the Gangpur area being younger than another, presumably the Eastern Ghats, trend. I have also referred to Lake's work in Malabar which shows that the foliation of the feldspathic schists having E.W. strike (which is presumably hat of the Eastern Ghats strike near its termination in this region),

'flows' around the masses of quartzose gneisses having the Dharwarian trend of the Western Ghats. In the Nellore region north of Madras, where some Dharwarian rocks with the characteristic trend are present, the Eastern Ghats belt seems to mould itself on the Dharwarian as it shows an eastward convex bend and again resumes its original direction (NNE and NE) near Madras City. It may be inferred from these that the Eastern Ghats orogeny is younger than the Dharwarian. I have also pointed out above that the Eastern Ghats appear to have been affected by a later, *i.e.*, post-Cuddapah, diastrophism along the same belt. Hence, the data from age determination of pegmatite minerals do not dispose of Fermor's contention that each of the orogenic belts may contain rocks of different ages. The correlation of the formations of the different belts can be solved mainly by careful structural studies. These can, of course, derive some help from radioactive age determinations of minerals whose sources can be dated with confidence.

It is known that there is a ridge beneath the alluvium in Punjab trending in a north-westerly direction from Hissar (west of Delhi) to near the Salt Range. This rises above the alluvium only at a few places near the north-western end, in the Kirana and Sangla Hills 40 miles to the SSE of the Salt Range. These hills extend over a distance of some 60 miles in a NW-SE direction, which is also the strike of the rocks composing them. These rocks are Pre-Cambrian and are entirely different from any in the Salt Range and are more related to those of the Aravalli mountains (Heron, 1913, p. 229). Auden (1949, plate XI and p. 153) regards this ridge as a continuation of one of the western ranges of the Aravallis which would thus have a sigmoidal shape when followed from western Punjab through Rajputana to Dharwar and Mysore. This Punjab ridge, it will be noticed, is parallel to the Himalays, and is flanked on its north by a trough similar to the Gangetic trough or foredeep in Bihar, in front of the Himalayas. The structure and history of this ridge is not easy to decipher as it is entirely covered over by alluvium except for the few hills rising above the alluvium near the Salt Range.

## 4. The Assam Plateau and Wedge

The Assam plateau, of which the outlying Mikir hills are undoubtedly a part, consists mostly of Archaean and Pre-Cambrian rocks, overlain along the southern margin by the Sylhet traps (Jurassic) and Cretaceous and Tertiary sediments. At and near its western end the rocks of the plateau show the Satpura trend, while in much of the rest of the area the trend is that of the Eastern Ghats. Though now separated from the main peninsular area by a broad strip of the Ganges-Brahmaputra alluvium, there is no doubt that the Assam plateau is part of the Peninsular shield. It appears to have been covered by the sea from the Jurassic or Cretaceous onwards and to have experienced the effect of the Tertiary

movements of the Himalayan and Burmese arcs in that it was uplifted in the Miocene. The Himalayas are thrust towards it in a southerly direction and the mountains of the Burma border in a westerly and northwesterly direction. Fox (*see* Heron, 1937) says that the plateau is sliced by a system of faults which run N.-S., *en echelon*, each faulted slice having been shifted slightly to the south of the one immediately on its west. The Assam block continues to the north-east as a wedge, submerged under the Brahmaputra alluvium, for its influence is felt in the Sadiya region and beyond, where occurs a remarkable hair-pin bend in the strike of the Himalayan formations. This critical region is unfortunately little known geologically, but there seems to be no doubt that the Himalayan formations continue into the Burmese arc comprising the Patkoi, Manipur and Arakan mountains (Wadia, 1936). The continuity seems to be partly interrupted in the Sadiya frontier tract and Mishmi Hills which expose highly metamorphosed Archaean rocks with NW-SE strike. To the east of this, in the Hukawng Valley and Fort Hertz area. there are Archaean schistose rocks and granitic intrusives but these may possibly belong to the Burmese province. The effect of the Assam wedge is seen far to the north-east in south-eastern Tibet and south-western China. The mountain chains of that region show a sharp north eastward flexure or convexity. The great rivers of south-east Asia—the tributaries of the Brahmaputra, the Irrawaddy, the Salween, the Mekong, the Yang-tse—rise in a small tract north of Upper Assam, and after flowing some distance southward, diverge widely and flow finally into the Indian Ocean or the Pacific as the case may be.

In the western part of the southern border of the Assam plateau, the Cretaceous and Tertiary rocks are overthrust by older rocks from the north. Followed eastwards, this overthrust zone passes into a monoclinal fold whose southern limb plunges steeply into the alluvial plains below. Further to the east, the same zone takes a north-easterly direction and merges into a thrust fault—*the Haflong-Disang thrust*—but now the thrust is from the south-east, from the side of the Burmese age. This thrust marks the north-western limit of the Disang series of Eocene age.

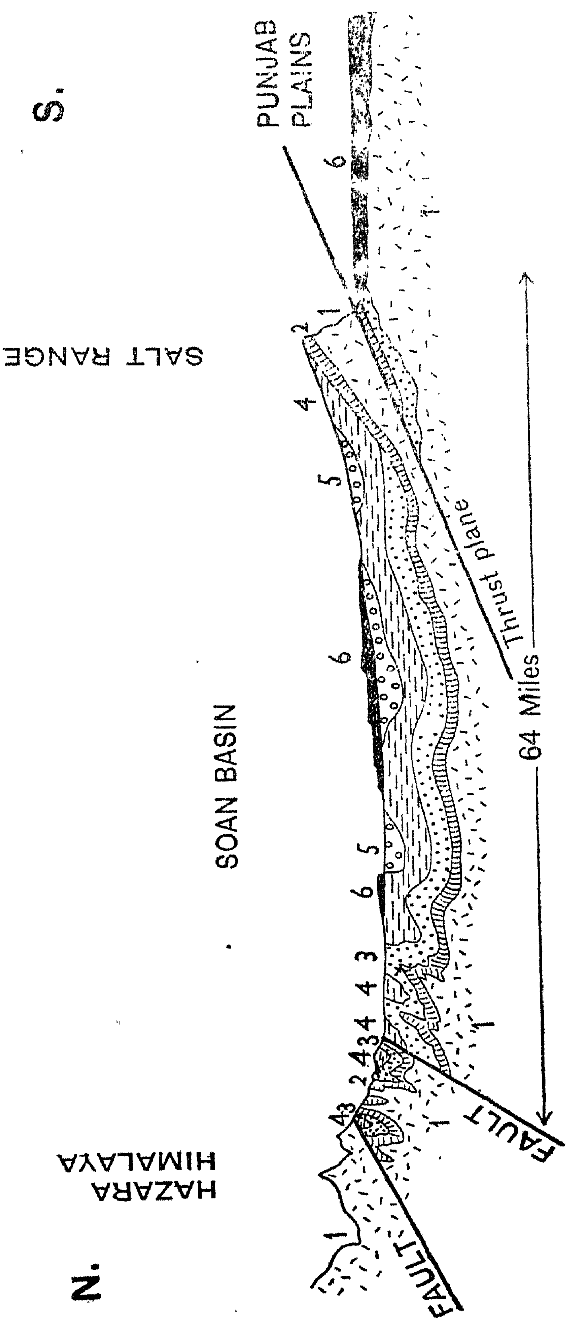
More or less parallel to, and some distance north-west of, the Haflong thrust, is another thrust fault, also directed to the north-west. This is called the *Naga thrust*. It is close to the border of the Brahmaputra alluvium in Upper Assam. Several producing oil wells have been drilled in the Tertiaries involved in the Naga thrust. Numerous other parallel strike faults and overthrusts are seen in the Naga hills to the south-east, even beyond the Haflong-Disang thrust.

The northern border of the Assam Plateau is faulted and presents a scarp towards the plains of the Brahmaputra. Like the Ganges in Bihar, this river also flows through a trough in front of the folded Himalaya mountains.

## 5. The Punjab-Kashmir Wedge

A similar effect is produced by the Punjab-Kashmir wedge in the north-west. The Potwar plateau of western Punjab is a synclinal trough with its axis along an ENE-WSW direction (Fig. 2). The northern border, adjoining the Kala Chitta and Margala hills, is closely folded into steep isoclines and recumbent folds, but the main syncline contains more open folds dipping north with strike faults hading in the same direction. It has probably a sub-stratum of Mesozoic rocks but exposes only Murree (Oligo-Miocene) and Siwalik (Mio-Pleistocene) fromations while along its southern edge Eocene rocks appear. The total thickness of Tertiary sediments aggregating to 25,000 ft., epitomises the Tertiary geology of Punjab and Kashmir (Anderson, 1928 : Wadia, 1932a). The southern border of this plateau is the Punjab Salt Range which presents a conspicuous scarp showing Cambrian sediments followed by a complete succession of marine rocks ranging in age from the Carboniferous to Eocene, and lacustrine and fluviatile sediments of Oligocene to Miocene ages which overlie them and extend northwards over the plateau. The Salt Range shows a faulted flexure in the east which, when followed westwards, is resolved into three parallel overthrusts. The upper limb of this disrupted fold has been thrust over the lower, completely obliterating the latter. The distance over which the rocks have been thrust has been estimated at not less than 20 miles (Gee, 1934a, p. 462). Saline marls associated with gypsum and dolomite appear in all sorts of positions in the overthrust zone and their stratigraphical position has been a source of controversy in Indian geology for many decades.

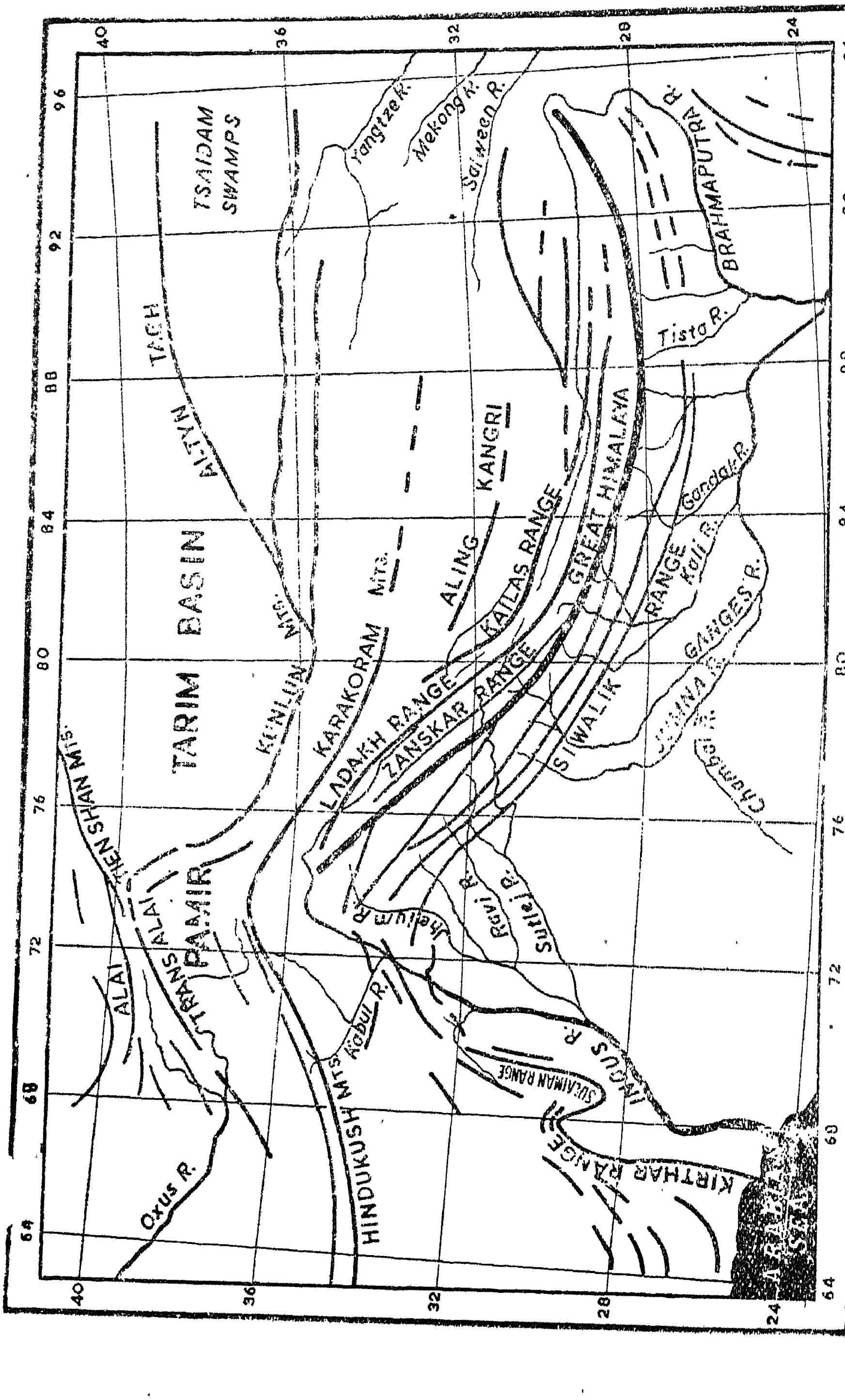
The presence of a wedge of the Peninsula projecting from North-west Punjab into Kashmir is inferred from the spectacular hair-pin bend of the geological formations in north-western Kashmir, some 75 miles north-west of Poonch. This is the Kashmir-Hazara Syntaxis described by Wadia (1931, 1938). On both sides of the bend, the formations have a NW-SE strike, but the southwestern side soon turns southwards and sweeps in a broad arc convex towards India. Mesozoic and Tertiary sediments as well as the Pre-Cambrian Salkhala formations are affected by this sharp flexure. Around this bend, the overthrust is directed from all sides towards the axial direction (Fig. 5). The effect of the wedge is seen as far north as the Karakoram—Hindu Kush ranges, the Pamir and East Ferghana, as will be seen from the northward bend of all the mountains and of the geological formations north of Kashmir (Hayden, 1915). Mushketov (1929) states that in the Alai Range, which forms the southern border of E. Ferghana in Russian Turkestan, there is an earlier (Tien-shan) folding from the north and a later (Himalayan-Alpine) folding and thrusting from the south which has an imbricate character. It is only in the Red Trough of Alaiku, occupied by red Cretaceous sandstones,




1. Pre-Tertiary 2. Eocene 3. Murree Series 4. Lower Siwalik 5. Upper Siwalik 6. Sub-Recent

SECTION ACROSS THE POTWAR GEOSYNCLINE

Fig 2. (After D. N. Wadia.)




HIMALAYAS AND CENTRAL ASIAN MOUNTAIN RANGES

Fig. 3.

that the effects of the Tien Shan folding from the north, and of the Himalayan folding from the south, are not noticed.

The effect of two other wedges is seen in the Baluchistan arc. One of these wedges is directed towards Sibi and Quetta and the other northwest from Dera Ismail Khan just south of the Salt Range. In each of these regions the festooning effect of the wedge is conspicuously seen, both in geological and topographical maps.

It would appear that these wedges which are, so to say, underthrust into the mountain belt bordering northern India, are responsible for the high seismicity of the regions lying near their tips (Sadiya, Pamir and Quetta areas) as the disturbance in the sub-crustal part of these regions may be much greater than elsewhere along the belt and will take a longer time to die off and attain equilibrium.

## 6. The Purana Formations

(Cuddapahs and Vindhyans).

The practically unfossiliferous upper Pre-Cambrians are known as the 'Purana' formations in India. They comprise the Cuddapahs which are entirely Pre-Cambrian, and the Vindhyans which are probably partly Pre-Cambrian and partly younger and contain discoid fossil impressions assigned to the genus *Fermoria* (Chapman, 1936 ; M. R. Sahni, 1936 ; Misra and Bhatnagar, 1950). They are exposed in the Aravalli fold belt of Rajputana and in three large crescent-shaped areas in Central, Eastern and Southern India. The southern one is the Cuddapah Basin containing Cuddapah and Kurnool (Vindhyan) sediments, which were deposited over the Archaeans after an interval of erosion. The eastern concave margin of this basin, which is parallel partly to the trend of the Dharwarian and partly to that of the Eastern Ghats rocks, is, unlike the western margin, highly disturbed and folded. The older sediments in this basin are the Cuddapahs and the later ones the Kurnools. The Cuddapahs contain intrusive basic sills and have been folded and disturbed to some extent, while the Kurnools are practically unaffected.

The Aravalli belt of Rajputana contains the Delhi System which is considered to be the equivalent of the Cuddapahs, though it has been subjected to intense diastrophism and intruded by granites and other igneous rocks. It is best developed in the synclinorium and extends down to Gujarat, where it pitches downward. It is overlain by the Vindhyan system of rocks which occur mainly in the neighbouring areas.

To the east of the Aravalli belt is the great Vindhyan basin of Northern India, occupying an area of some 40,000 sq. miles. It has also a crescentic

shape, the northern concave margin enclosing the Bundelkhand granite of Archaean age. Its western margin against the Aravalli fold belt is marked by a reversed fault or overthrust, the upthrow on the western side being estimated at 5000 ft. (Oldham, 1893 p. 103) or 3500 ft. (Heron, 1938 p. 128). The Aravallis are brought up against the Bhander Sandstone (Upper Vindhyan) along the fault. This fault, which is parallel to the trend of the Aravallis, and has been traced over a distance of 500 miles or more, is definitely post-Vindhyan and may belong to the Hercynian orogenic period or even to the Mesozoic. Uraninite and monazite from pegmatites intrusive into the Delhis indicated an age of 700 to 865 million years (Holmes, 1949).

The Vindhyans comprise two major divisions, the Lower Vindhyan or Semri Series, and the Upper Vindhyans. The Semri series is seen near the outer borders of the Vindhyan basin in the Son Valley, near Chitor in Rajputana and in the Dhar forest on the edge of the Narbada alluvium east and south-east of Bhopal. The Semris are intruded by basic lavas and show much disturbance and folding. The rocks of the Dhar forest exhibit folding along a NW-SE axis which apparently continues in a northwesterly direction, underneath the Deccan Trap, to Jhalrapatan southeast of Kotah.

The Upper Vindhyans, with which the Kurnools are correlated, consist largely of sandstones and shales deposited in shallow waters and partly under semi-arid conditions as witnessed by the false-bedding of the sandstones, their red colour and the occurrence of gypsum in some of them. They are generally undisturbed except near the southern and southeastern edges of the basin. The movements on the south-western side have come from southwest whereas in the eastern areas they appear to have come from the south or south-south-east, controlled by the earlier Satpura strike.

The third large area is the group of exposures in Bilaspur, Raipur, Bastar, etc., in the Cetral Provinces which are taken generally to represent the Cuddapahs, and perhaps also the Vindhyans, in part. Here also the more eastern outcrops show some disturbance on the eastern side adjoining the Eastern Ghats. A few other patches of Purana rocks are found along the Godavari Valley and in the Kistna and Bhima Valleys of Southern Bombay and Hyderabad. In these last, the Kaladgi formations (presumed to be the equivalents of the Cuddapahs) are said to be intruded by granite (Iyer, 1939, pp. 518-520).

A fact to which attention should be drawn is that the Delhis, Pakhals Kaladgis and the Puranas of Raipur-Sambalpur area of Orissa and the Central Provinces (V.S. Krishnaswami, 1951) are all intruded by granites. Since the Cuddapahs of Madras, with which these are generally correlated, have not been subjected to granitic intrusion, there are

grounds for reconsideration of such a correlation. As pointed out by Mahadevan (1949), these groups may be really older than the Cuddapahs. The question will have to be kept open until more field and laboratory data on the age of these various groups become available.

It should be stated, however, that while strong mountain building movements affected the Delhi formations, their presumed equivalents in South India experienced comparatively less intense activity. The Lower Vindhyans (Semris) were also subjected to movements of some magnitude, but there is some doubt whether these formations do not really belong to the Cuddapahs. The Upper Vindhyans are everywhere practically unaffected by earth movements except in the Bundi-Karauli region of Rajputana where they are folded to some extent.

There are no formations in Peninsular India younger than the Vindhyans until we reach the period of glaciation in the Middle or Upper Carboniferous. During the whole of this interval, the Peninsula was apparently unaffected by any strong orogenic movements though the Vindhyans must have been uplifted and all land subjected to denudation. If any deposits had been laid down during this interval, they must have been removed completely by erosion.

## 7. The Gondwana Formations

Gondwana sedimentation was initiated by large icesheets which covered the greater part of the Peninsula and whose motion was responsible for the laying down of the Talchir tillite in Eastern India, the Salt Range and parts of the Himalayas. The direction of ice movement was towards the north in Eastern India and north-west in the Punjab, for we find some characteristic Rajputana rocks amongst the boulders of the Salt Range tillites. In the Himalayan area there are tillites presumed to belong to this age in Kashmir and Hazara (Tanakki and Talhatta boulder-beds), in the Simla-Garhwal region (Blaini and Mandhali boulder-beds), in the Kosi river Valley in Nepal near Barahakshetra (Auden, 1946, p. 346), in the Permo-Carboniferous Lachi Series of North Sikkim (Auden, 1935, p. 155 ; 1946, p. 346) and at several places in the Sub-Himalayan zone up to east longitude 95°. It is thought that Gondwana glaciation extended to some distance north of Lachi (28°1′ : 88°45′) for the beds in the Lachi Hills must originally have lain further north and brought to their present position by thrusting.

According to Fox, the coal-bearing formations of the Lower Gondwanas were laid down by extensive river systems which flowed from high-lands situated to their south and east. It is therefore likely that the Aravalli-Central India region, the Eastern Ghats and South India constituted high-lands, which might have been depressed to some extent

by the load of ice. The tillites appear to have been deposited in the sea along the northern border of India and in the Salt Range area.

At about the same time, great orogenic disturbances (the Hercynian revolution) were taking place in Asia and Europe, and there is evidence that the Western Altai, Tien-Shan, Kun-Lun, Karakoram, Nan-Shan and Tsin-Lin ranges came into existence. A great mediterranean sea, stretching west to east from Southern Europe through the Balkans, Turkey and Iran to the Himalaya, came into existence. This stretched out further east through what is now the Assam-Burma border and the Arakan mountains. This sea, called the *Tethys* by E. Suess, persisted throughout the Mesozoic but gave place to mountain ranges in the Tertiary. The history of this geosyncline will be dealt with in some detail later. A depression or rift seems to have been formed at about the same time along the valley of the Narbada as far east as Umaria (23°32′ : 80°50′) and perhaps extending further east. The Umaria region was apparently connected through Gujrat and Cutch to the arm of the Tethys stretching into the Salt Range and Baluchistan. The reason for this statement will appear later (see below).

The close of the glacial period is marked by Talchir shales and sandstones containing grains of undecomposed feldspar. This was followed by a cold temperate climate during which the *Glossopteris* flora flourished throughout the southern continents and India. The chief coal-bearing beds in India are the Barakar and Raniganj series, of Lower and Upper Permian age respectively, separated by barren sandstones. The coalfields are situated along three major zones of block faulting (graben), *viz.*, along the Damodar-Son, Mahanadi and Godavari valleys. In the Damodar-Son Valley the southern sides of the blocks are more deeply faulted than the northern; in the Godavari and Mahanadi basins the north-eastern sides are faulted down more than the south-western. The faulting may, to some extent, have taken place *pari passu* with the sedimentation.

In the Umaria basin mentioned above, a small outcrop of marine Lower Permian rocks was found a few years ago, overlying the Talchir tillite and underlying the Barakars. This zone is rich in Productids and a few other genera of brachiopods and some small gastropods; these have some similarity to the Salt Range fauna and are assigned to the Permo-Carboniferous, *i.e.* equivalent to the Speckled Sandstone group and the *Eurydesma* and *Conularia* beds of the Salt Range (Reed, 1928). Since it is only in Kathiawar and Cutch that there are marine strata younger than these beds, and since it is known that the Narbada valley is a zone of weakness, it appears most probable that the Salt Range sea was connected with Umaria through these regions (Krishnan, 1949, p. 284).

In the Salt Range area, the Talchir tillite is immediately overlain by shales containing impressions of *Gangamopteris*, *Glossopteris* and spores probably belonging to these and allied plants (Virkki, 1937, 1939). Many of these spores were found to be almost identical with those of the Bacchus Marsh beds of S.E. Australia (B. Sahni, 1939). These tillites are overlain by the Olive series containing *Eurydesma* and *Conularia*-bearing horizons. The Olive series is overlain by the Productus Limestone group of Permian age.

In Kashmir, the Hercynian revolution produced land conditions in some parts and the Panjal volcanic episode commenced. The Agglomeratic Slates of Upper Carboniferous age contain intercalations of marine strata with Productids, Spiriferids, *Fenestella*, etc., and also plant beds with *Gangamopteris*, *Glossopteris*, etc., and the amphibian *Archegosaurus*. An *Eurydesma*-bearing horizon is found just below the *Gangamopteris* beds. The plant beds are overlain by the Zewan beds containing marine Permian fossils similar to those of the Salt Range and the Spiti valley.

The volcanic episode and partial land conditions in Kashmir continued throughout the Permian and well into the Triassic, so that intermigration of plants between this area and Angaraland and Cathaysia was possible through the Pamir and Ferghana region. East Ferghana was characterised by continental conditions from the Upper Carboniferous to the Jurassic and a marine transgression took place only in the Cenomanian, according to Mushketov (in Gregory, 1929). The Hercynian revolution produced land conditions also in Northern Afghanistan and Eastern Iran, which lasted through the Permian and Triassic.

In the Spiti Valley, north of the main Himalayan range, there was a *Rhacopteris* flora in the lower part of the Middle Carboniferous Po Series, whose upper part is marine. After the Hercynian revolution, the Tethys Sea was established in the Himalayan area.

Gondwana strata, often coal-bearing, are found in the Giridih and Rajmahal regions north and north-east of the Raniganj field of Bengal, where they have been faulted down along radiating fractures; along the western edge of the Garo Hills of the Assam plateau (Sale and Evans, 1940, p. 344); and at several places along the Sub-Himalayan zone eastward from Nepal up to about E. longitude 95° in the Abor Hills, where they are found generally crushed by the mountain building movements and overthrust by older rocks. It is therefore clear that the Lower Gondwana fluviatile and lacustrine sediments were laid down along the Sub-Himalayan region which formed the northern edge of the Peninsula.

The humid conditions which permitted the growth of luxuriant vegetation in the Permian gave place to dry continental conditions

in the Triassic. The sediments of this period are red sandstones and sandy clays (Panchet and Mahadeva Series) probably laid down in lakes. They have yielded remains of some amphibians and reptiles. The *Glossopteris* flora dwindled and gradually gave place to the *Thinnfeldia-Ptilophyllum* flora. The latter attained prominence in the Jurassic, when moist conditions returned again and the Rajmahal, Kota and Jabalpur beds were laid down. The differentiation which existed amongst the four distinct floras of the Permian (*viz.*, the Arcto-Carboniferous flora of Europe, the Angara flora of Siberia, the Cathaysian or *Gigantopteris* flora of China and the Gondwana or *Glossopteris* flora of Gondwanaland), had disappeared and the Jurassic flora became uniform all over the globe.

The Upper Gondwanas are well developed in the Rajmahal area at the head of the Ganges delta, in the Janakpur-Sohagpur area of the Son Valley, in the Jubbulpore and Pachmarhi regions in the Central Provinces, in the Godavari Valley, Gujarat, Cutch, Jaisalmer in Rajputana and a few places along the east coast. In the last, plant beds referable to the Jabalpur or Kota stages (Middle or Upper Jurassic) are associated with marine beds. Some ammonites in the marine beds, not too well preserved, have been assigned a Neocomian age by Spath (1933) from their evolutionary characteristics. The East Coast Gondwanas may therefore be of Middle Jurassic to early Cretaceous age, and indeed, Cotter (1938, p. 36) was of the opinion that the Upper Gondwanas of the East Coast were of Lower Cretaceous age. In the Rajmahal Hills, plant-bearing beds occur intercalated with thick lava flows. These are thought to belong to the Middle Jurassic. The Sylhet Traps of the Assam plateau and the lavas in the Abor Hills of the eastern end of the Himalayas, as well as the dykes of lamprophyre, peridotite and basalt which traverse the eastern coalfields, are all regarded as of the same age.

The chief phase of block-faulting which affected the Gondwana strata in India may be of Upper Triassic to Lower Jurassic age. In the Damodar valley coalfields, most of the dykes (presumed to be of Rajmahal, *i.e.* Middle Jurassic, age) are later than the faults traversing them. In the Karanpura coalfields some faults are pre-Mahadeva (pre-Upper Triassic). The boundary faults of the Damodar Valley coalfields run practically E-W, more or less *en echelon*, but in the Son valley area they run ENE-WSW, parallel to the Satpura trend and the Narbada rift. There is a series of fractures associated with block-faulting, radiating to west, north-west and north from the Raniganj area in W. Bengal, and in these are situated the several small coalfields of southeastern Bihar including the Giridih and Rajmahal fields. These may have been contemporaneous with the fissures through which the Rajmahal Trap was erupted. Whether other fractures were formed trending

north-east from the same focus towards Bhutan, is a matter of speculation, as that direction is entirely covered by the Gangetic alluvium. If such fractures did exist, they would have been the fore-runner of the Garo-Rajmahal gap about which there has been much discussion recently (Hora *et. al.*, 1949).

After this period, and probably in the Middle Cretaceous, the Gondwanas underwent folding movements which affected the strata in the Son valley more than those in the Damodar valley, though the latter also have been affected to some extent. The age of this movement was post-Jabalpur, for there is a large unconformity between the Jabalpurs (Upper Jurassic) and the Lametas (Upper Cretaceous). We often find horizontal traps resting on the folded Gondwanas with a marked disconformity. The base of the Gondwanas is found at different elevations in different places (Auden, 1949 a, p. 320)—200 ft in Bengal and 3,000 ft. in Sohagpur and Chhindwara in the Central Provinces. Where depressed by block-faulting or folding, the base is several hundreds or thousands of feet below sea-level, *e.g.*, 400 ft. or more in the chief troughs. The age of the folding was probably the same as that which affected the Jurassic rocks of Cutch in Middle Cretaceous times (post-Aptian and pre-Maestrichtian) which will be adverted to later.

We may now turn to the Extra-Peninsular region comprising the Himalayan, Burmese and Baluchistan arcs and consider the sequence of events there as well as along the coasts of India.

# THE EXTRA-PENINSULAR REGION

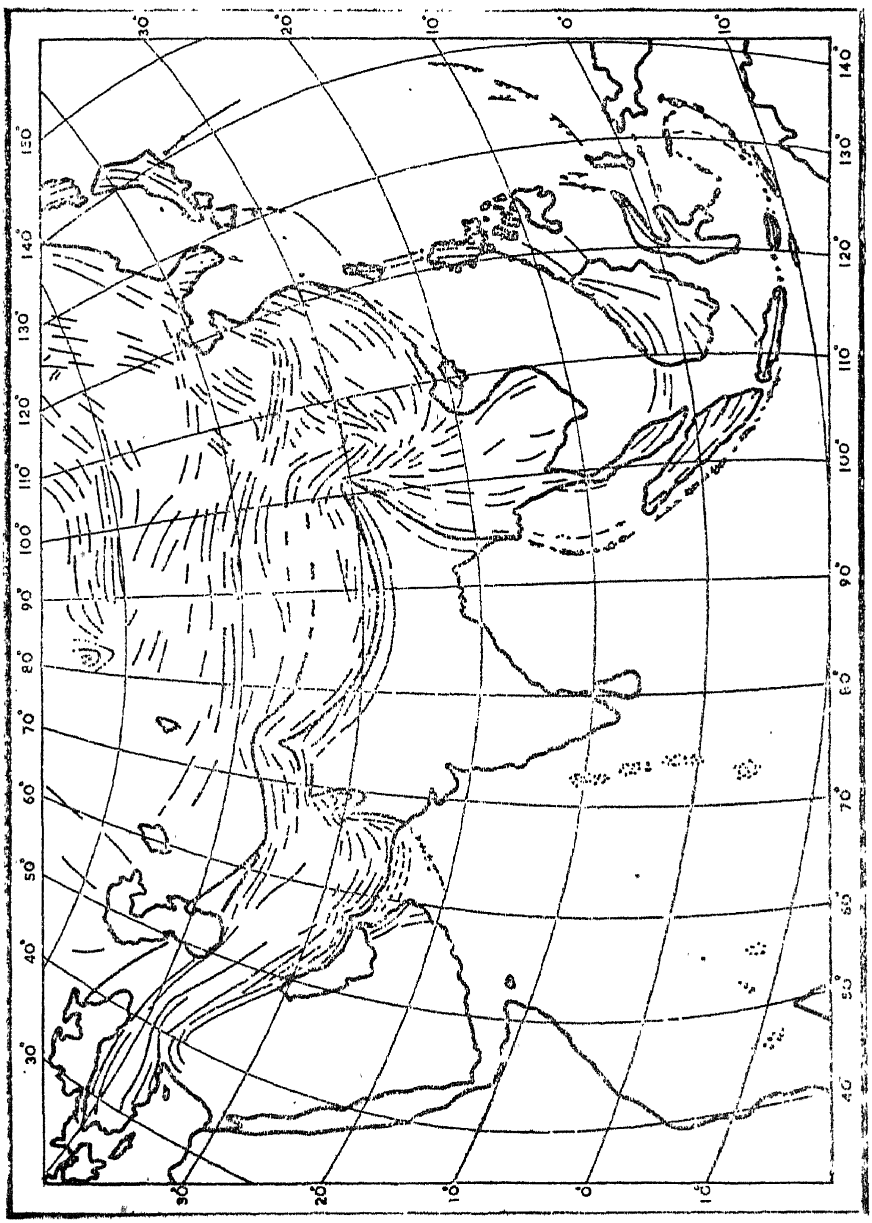
## 1. The Himalayan Arc

The Himalayan arc lying to the north of India is one of immense radius and extends from Nanga Parbat (26,620 ft.) on the west to Namcha Barwa (25,445 ft.) on the east. The term 'Himalayan Arc' is used here in an orographic and geographical sense to designate the unit comprising the Himalayan mountain chains for, geologically and structurally, it continues into the Baluchistan and Burma arcs at either end, as will be made clear later (Wadia, 1931; 1932; 1936). It consists of a series of more or less parallel ranges which are succeeded further north by still more ranges. But in that direction the curvature of the successive ranges gradually lessens.

The Himalayas are generally divided into four longitudinal zones. The outermost, bordering the north Indian plains, consists largely of the Siwalik formations (Mio-Pleistocene), forming low hills and of varying width, up to 30 miles wide. The next is the Sub-Himalayan zone (also called Lesser Himalayas), about 50 miles in width and on an average 7,000—10,000 ft. in altitude though some points are much higher. It contains sediments of various ages from the Pre-Cambrian upwards, most of them generally unfossiliferous. Amongst them are the Talchir tillites at the base of the Gondwanas as well as coal-bearing Lower Gondwanas at many places. This contains several overthrusts and nappes in which recumbent folds and inverted sequences are common. This represents the border of the former land mass of India and the marine basin which lay immediately beyond. Beyond this comes the Central Himalayan zone, some 40 miles wide, containing practically all the snow-clad high peaks. It consists of some sedimentary and metamorphic rocks and large masses of igneous intrusives. The Central Himalayan granite is probably of different ages, largely Kainozoic and possibly partly Mesozoic. Beyond this is the Himalayan Tethyan zone composed of sediments of all ages formed in the Tethyan geosyncline. It contains the valleys of the Indus and the Brahmaputra draining the northern ranges of the Himalayas, the altitude of the river basins being about 12,000 to 14,000 ft.

Between the Tethyan zone and the Karakorum Mountains is the little known region of Tibet, containing the Aling Kangri and the Trans-Himalaya ranges of Seven Hedin, the latter being the real watershed between India and Tibet. The Karakorum range is roughly parallel to the Himalayas but is bent northwards in the Pamir region beyond which its western continuation is called the Hindu Kush. Still further north is the Kun Lun range which has

also been affected by the Alpine-Himalayan orogeny. The Pamir region is a mountain knot showing the remarkable feature of radiating mountain chains.



MOUNTAIN ARCS OF SOUTHERN ASIA

We shall now proceed to give a short description of the structure of the Himalayas as deciphered in the few areas in which they have been examined in some detail in recent years.

Commencing with Kashmir, at least three major thrust zones are recognised in the Siwalik and Lesser Himalayan region. The southernmost is the *Main Boundary Fault* which usually separates the Siawliks from the earlier Tertiaries and older rocks. To the north of the Tertiary belt is the autochthonous (more correctly para-autochthonous) zone

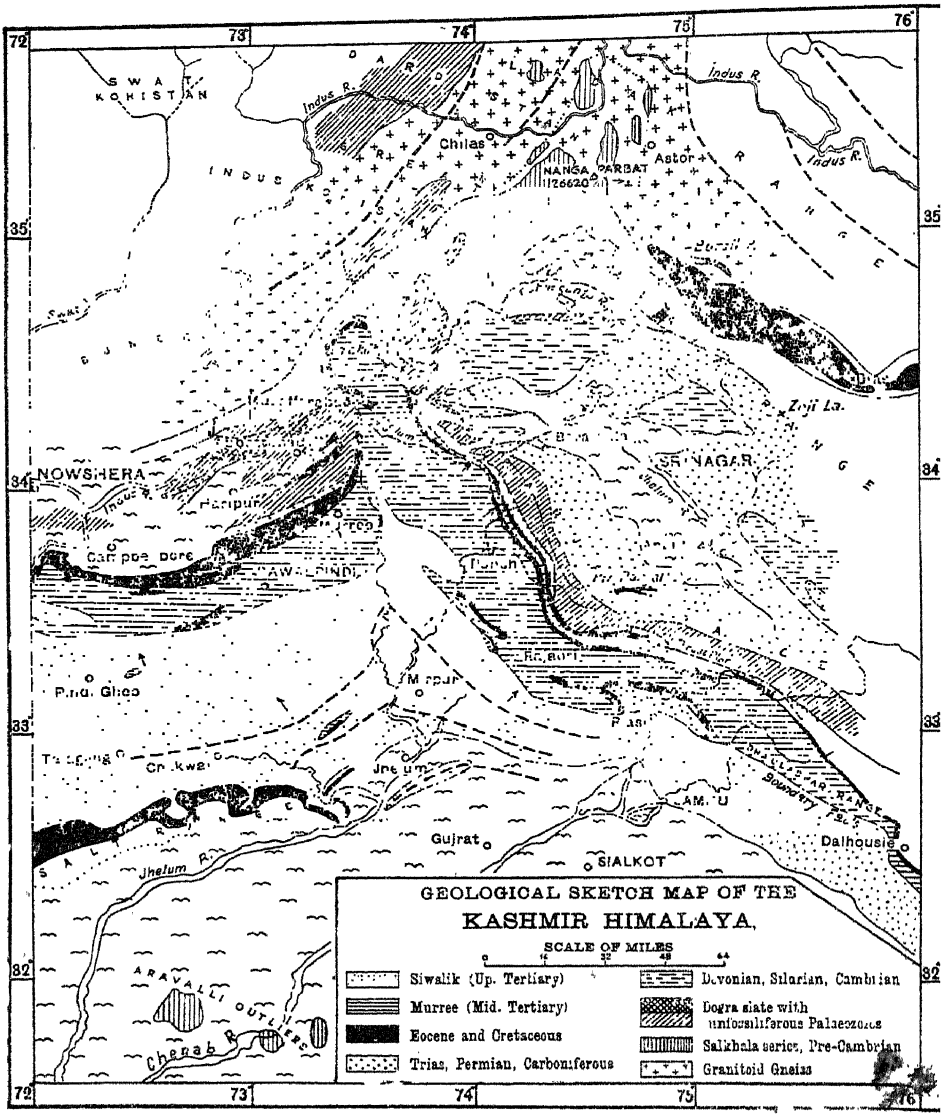
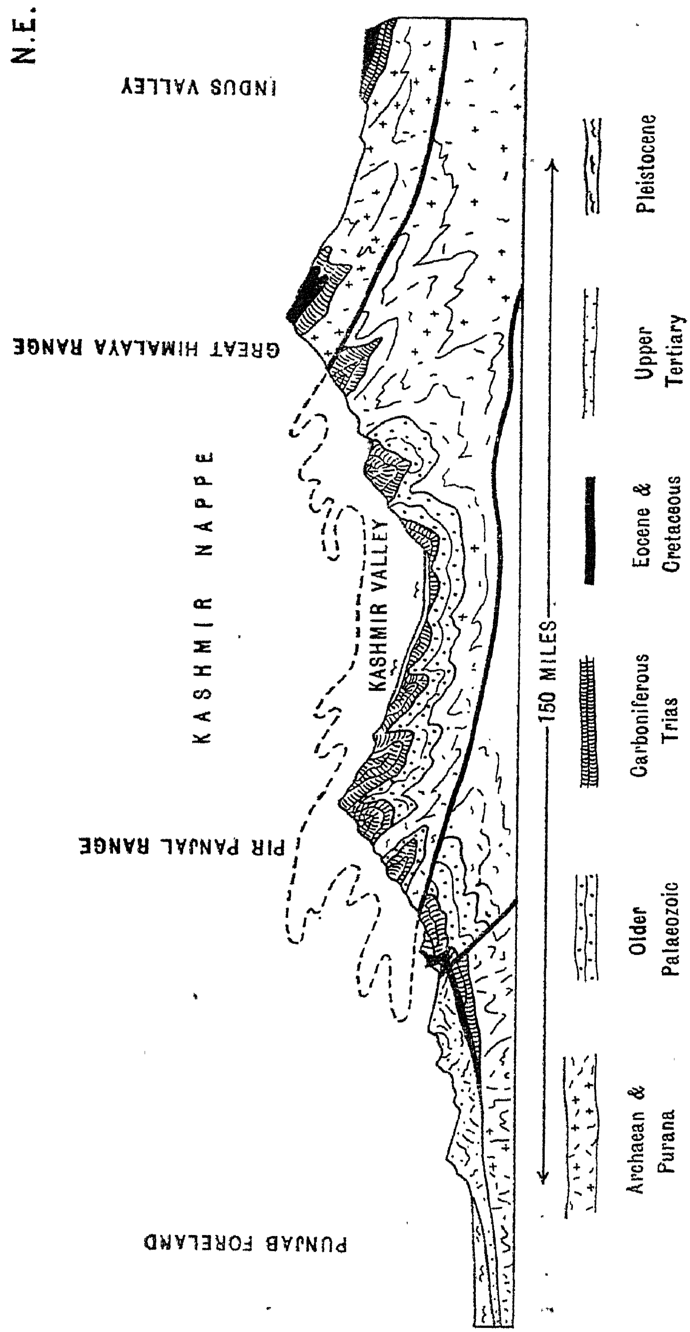



Fig. 5. (After D. N. Wadia.)

containing sediments of all ages from the Carboniferous to the Eocene. These are folded and thrust over the rocks of the foreland. This thrust is called the *Murree thrust.* Beyond this is the zone of nappes (Kashmir nappes) in which at least two important thrusts are known to be present.




SECTION ACROSS THE KASHMIR HIMALAYA TO SHOW THE BROAD TECTONIC FEATURES

(After D. N. Wadia

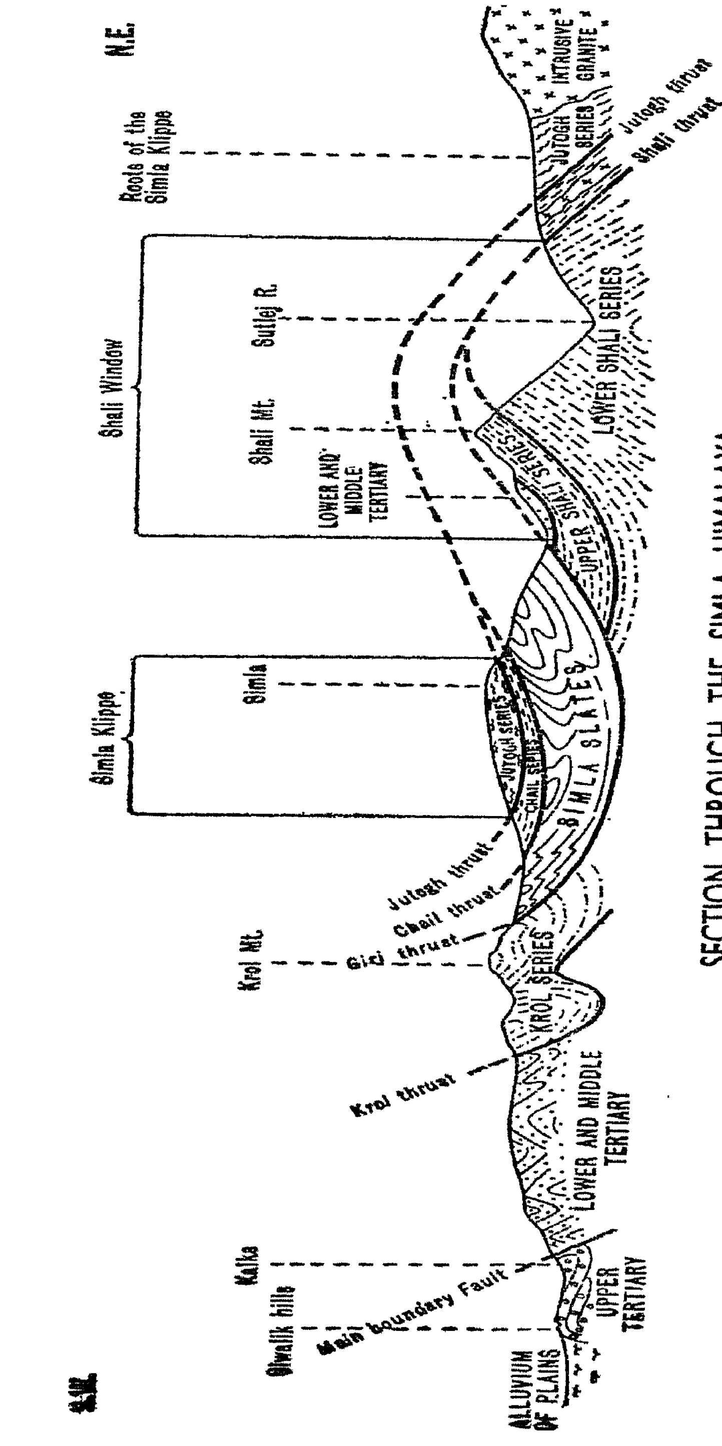
Fig. 6.

The Pre-Cambrian, Palaeozoic and Mesozoic rocks of the nappe zone are thrust over those of the autochthonous zone. These constitute the *Panjal thrusts*. Further to the north is the Central or Main Himalayan Range intruded by granites of presumably Cretaceous and Tertiary ages (Wadia, 1934 ; 1938 ). Fig. 5 shows the geology of the Kashmir region while Fig. 6 shows a hypothetical section across Kashmir.

In the Simla region, which has been mapped by Pilgrim and West (1928 ; West 1934) and by Auden (1934), the *Main Boundary Fault** separates the Middle and Upper Tertiaries from the Lower Tertiaries which have been thrust over them. The Upper Tertiaries, which have a width of over 60 miles in Kangra, become narrowed down to barely 16 miles near Solon, south of Simla. The Tertiaries are separated from the pre-Tertiary rocks of the autochthonous belt by the *Krol thrust* which thus corresponds to the Murree thrust of Kashmir. Beyond this is the zone of nappes with the *Jutogh* and *Giri thrusts*. Further north is the important *Chail thrust* with its Pre-Cambrian and Palaeozoic rocks, under which the Shali window described by West (1939) exposes the Shali limestones, slates and quartzites (Mesozoic), as well as Madhan slates (Tertiary). Nummulitics and Dagshai beds (Miocene) have also been found in the above-mentioned window. Granitic intrusives are found in the nappe zone and along the Main Himalayan range. The nappe zone shows several klippen of highly metamorphosed ancient rocks resting on less metamorphosed unfossiliferous Palaeozoic and later rocks (Fig. 7).

To the E.S.E. of Simla is Garhwal where the *Main Boundary Fault* separates, as usual, the Siwaliks from the autochthonous zone of Simla States (Palaeozoic) overlain by Nummulitics and other Lower Tertiaries. This zone is over-ridden by the Krol nappe (Krol thrust) which contains rocks of various ages from the Pre-Cambrian to the Mesozoic (Fig. 8 and Pl. 1). The Giri thrust unit lies over the Krol thrust unit of the Simla area which is known to extend to the east beyond Naini Tal. Further north are the Garhwal nappes which bring highly metamorphosed Pre-Cambrians and some Palaeozoics over the Krol belt (Auden, 1934). The Garhwal nappes, with their roots in the Main Himalayan range, have also transported the granites with them. Both the Krol and the Garhwal nappes are folded, which Auden believes (1937, p. 429) may be due to the resistance offered by the floor over which they moved southwards. Since the Krol thrust overlies the Dagshai beds, it cannot

*There is some confusion in the use of the term *Main Boundary Fault*. It was originally used by H. B. Medlicott who suggested that it marked the boundaries of deposition of the Nummulitics from the post-Nummulitic rocks, or the Tertiaries from the pre-Tertiaries (Medlicott, 1865, *Mem. Geol. Surv. India*, III, Pt. 3, 81-84, 174). This idea is erroneous. The Main Boundary Fault is known to be a thrust zone which generally separates the post-Nummulitic Tertiaries from the pre-Nummulitics (West, 1937, *Proc. Ind. Sci. Cong.* p. 205 ; Auden, 1938, *Proc. Ind. Sci. Cong.* Pt. IV, p. 20.)




SECTION THROUGH THE SIMLA HIMALAYA.

Fig. 7

(After W. D. West.)

be older than the Burdigalian. The Garhwal thrusts cover the Nummulitics and may therefore be also of Miocene age (Auden, 1934). Several tectonic windows have been found in recent years in the Lesser Himalayan belt (Auden, 1937 ; 1951, figs. 4, 6).

Nepal and the Eastern Himalayas have not been examined in detail, but enough is known to enable us to say that the structure is similar to that of Garhwal and Kashmir. In Nepal, a thrust separates the Middle and Upper Siwaliks from the Lower. The Tertiaries are overridden by pre-Tertiary rocks (para-schists, Palaeozoics and Krol series)

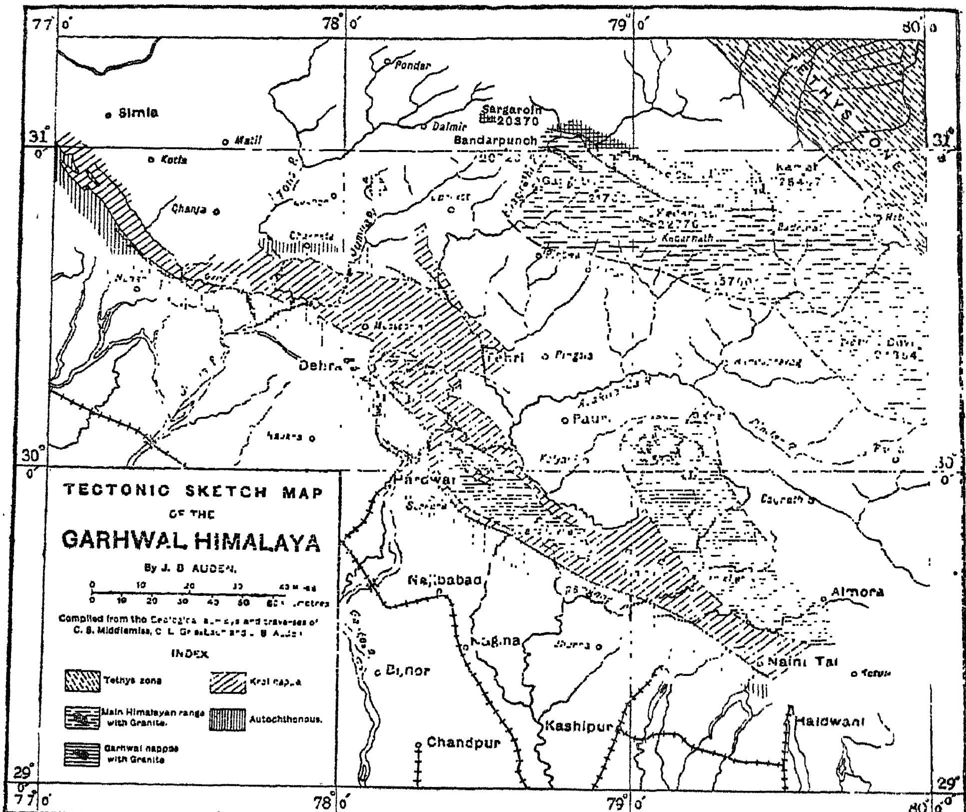



Fig. 8. (After J. B. Auden.)

by another thrust, seen near Sanotar. A third thrust brings the Pre-Cambrian Darjeeling gneiss and Daling schists over the above-mentioned zone (Auden, 1935, pp. 136-147).

Information on Sikkim is scattered, but here also the Main Boundary Fault and one or more other thrusts have been recognised. Coal-bearing Gondwanas are thrust over the Siwaliks in the Darjeeling foot-hills, the Gondwanas being in turn overlain by older rocks. Permian and Mesozoic sediments are exposed in Northern Sikkim and in the Mt. Everest

region where a glacial boulder bed is associated with the Permian Lachi series (Wager in Ruttledge, 1934, p. 333 ; Auden, 1935, pp. 147, 154).

In their important work on the Geology of the Himalayas, Heim and Gansser (1939) have reviewed the tectonics of the entire Himalayan belt from the plains of India to the Trans-Himalayna Range (Fig. 9).

The Siwalik zone bordering on the Gangetic plains is thrust over

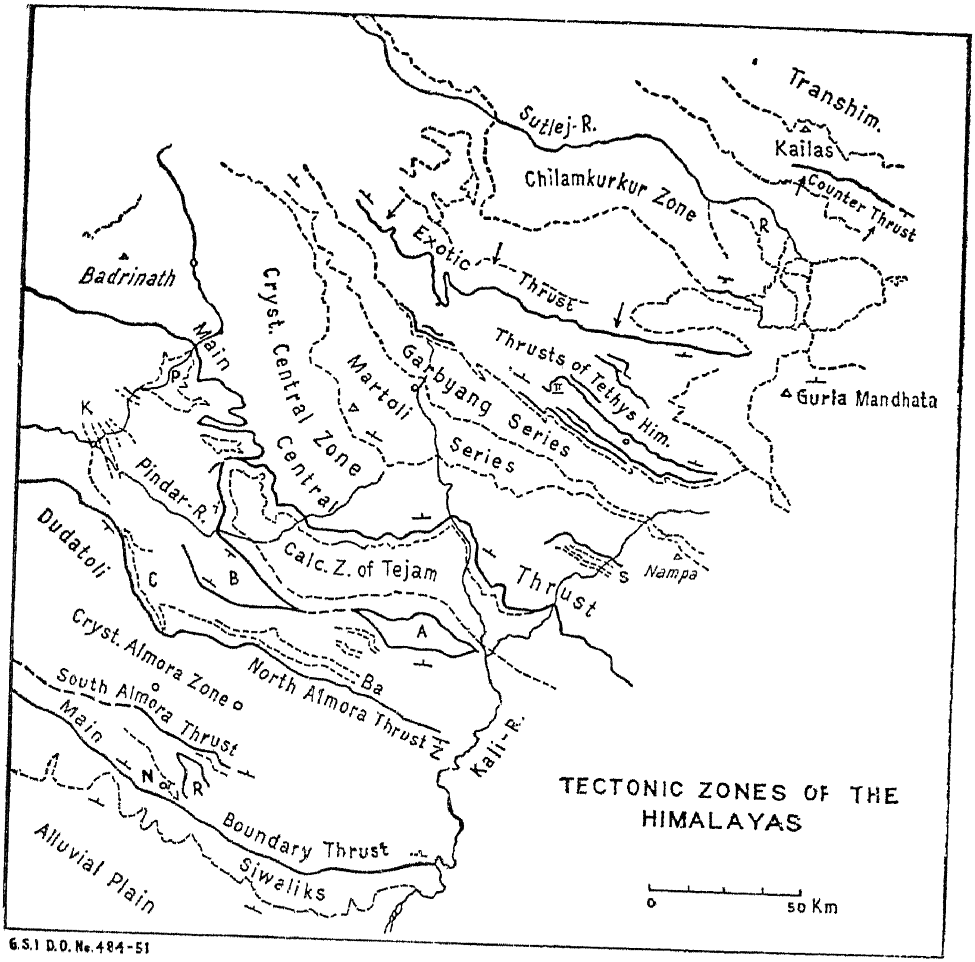



Fig. 9. (After A. Heim and A. Gansser.)

by the Miocene rocks in the Kalka region below Simla. The Karewa formations in Kashmir, of Middle Pleistocene age, are known to have been uplifted a few thousand feet on the flanks of the Pir Panjal range. The Second Inter-glacial deposits which contain the remains of early tool-making man have suffered uplift in North-western Himalayas, according to de Terra (1937 ; also B. Sahni, 1936, pp. 10-16). In parts

of the Eastern Himalaya, especially in the Darjeeling and Bhutan regions. the thrust masses have advanced on to the plains, the age of the thrust being later than the Upper Siwalik Conglomerate (*i.e.*, .Pleistocene).

The Lesser Himalayas of Garhwal show *at least four superimposed thrust sheets* lying over the Nummulitics and other rocks associated with them. According to these authors (1939, p. 219) the thrust synclinal of Naini Tal is the continuation of the Krol belt. This is thrust over by the gneisses, schists, etc. of the Ramgarh region and this again by the crystalline zone of Almora. The northern-most zone of the Lesser Himalaya is the calcareous zone of Tejam which may possibly represent the Krol-Tal succession though the rocks are much more metamorphosed than the typical Krol-Tal rocks.

After this appears the great crystalline zone of the Central Himalayas containing schists and ortho-gneisses invaded by huge masses of granite. These are thrust on top ot the Tejam zone.

Beyond this comes the Tethyan belt containing repeated thrusts Heim and Gansser have called the first of these the *Nihal thrust*. The second is the *Thumka Gad thrust* seen near Kuti which shows tight folds of Kioto limestone (Rhaetic), in the synclinal portions of which there appear the Spiti Shales (Jurassic). A third thrust appears near the Manshang Pass where the Silurian is repeatedly brought up against and over the Permo-Triassic rocks. All these are thrust over by the Cretaceous flysch associated with the exotic limestone blocks of Permian to Cretaceous ages and basic igneous intrustives and lava flows, from the north-east. These exotics and associated rocks do not belong to the Himalayan Tethyan belt but must have come from Tibet. The exotic blocks belong to a facies similar to the European Triassic Dachsteinkalk, Jurassic oolites, Cretaceous limestones, shales, crinoidal limestone and radiolarian cherts. The exotic blocks and associated rocks are repeated in the Shib Chu valley and also in the Amlang La and Jangbwa areas west of Raksas Tal.

Beyond this is the sedimentary zone of the Chilamkurkur and Raksas series which are dominantly shaly and of Mesozoic age. Still further north is the Darchen zone of flysch with associated igneous rocks and limestone blocks which might possibly represent the root zone of the Kumaon exotics mentioned above. But the Darchen rocks are thrust in a north-easterly direction—regarded by Heim and Gansser as a counter-thrust—over the Eocene conglomerate zone of Mount Kailas which here occupies a wide zone. Beyond Mount Kailas is the Trans-Himalaya Range with its granites and metamorphics

Summarising, we may say that the following thrust zones have been established from south to north :—

1. Imbricate thrusts of the Himalayan border and the Simla region.
2. Thrusts of the interior Lesser Himalayas.
3. Thrusts of the Crystalline Central Himalayan zone in which Mt. Everest and Kanchanjunga are included.
4. Repeated thrusts of the Himalayan Tethyan zone.
5. Thrusts of the Exotic block—flysch zone of Tibetan facies.
6. The counter-thrust Darchen zone which may be the root of No. 5.

The exotic block zones contain ultrabasic rocks including peridotites and serpentines, while the Central Himalaya and Trans-Himalaya contain large granite intrusions. These should represent the central and most highly disturbed belt of geosynclinal sedimentation which was subsequently lifted up into great mountain ranges.

Geographically, the Himalayas terminate at Namcha Barwa in the east. Some think that the eastern continuation of the Himalayas are to be looked for in the mountain ranges of South-Western China. Though that region is still little known, all the available knowledge goes to show that, geologically, the Himalayan formations turn sharply southward and form the Burma-Arakan ranges which will be referred to here as the Burmese Arc (Wadia, 1936). The north-easterly strike of the eastern end of the Himalayas turns sharply to a S.E. direction beyond the Sadiya frontier region, then S.W. and finally South. The Shan region of Burma is geologically a part of the Yunnan-Indochina Province, and its proximity to India was brought about only in post-Cretaceous times. Moreover, the drainage and ridge-pattern of the Assam-Tibet-Burma—S.-W. China region shows a radiating arrangement somewhat like that of the Pamir, as pointed out on a previous page.

## 2. The Burmese Arc.

This arc commences just beyond the north-east corner of Assam and sweeps in a broad curve through Arakan and Andaman islands into Sumatra and beyond (Fig. 10). It is convex towards India but there is a slight concavity in the Arakan region, probably due to the existence of a part of the Peninsular shield under the Ganges-Brahmaputra delta. The southern part of the Burmese arc is largely submerged in the Bay of Bengal, the Andamans and Nicobars being the unsubmerged peaks of its ridges. Our knowledge of the geology of the Assam-Burma border is sketchy, but it is known that the mountain ranges here are composed of folded Mesozoic and Tertiary rocks, intruded by granitic and ultrabasic rocks. In the core of this belt are Triassic and Cretaceous

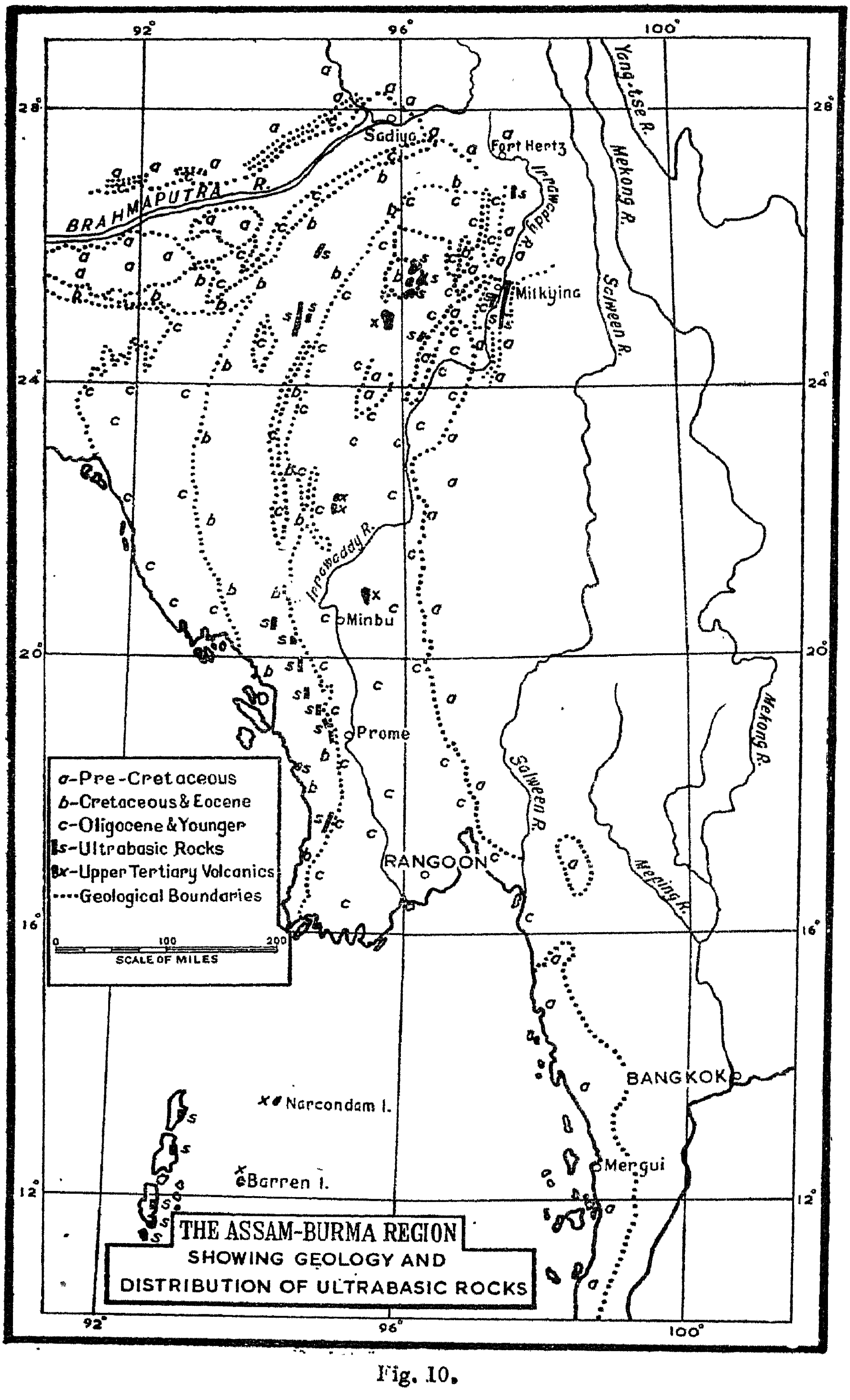

THE ASSAM-BURMA REGION
SHOWING GEOLOGY AND
DISTRIBUTION OF ULTRABASIC ROCKS
a-Pre-Cretaceous
b-Cretaceous & Eocene
c-Oligocene & Younger
s-Ultrabasic Rocks
x-Upper Tertiary Volcanics
....Geological Boundaries
0 100 200
SCALE OF MILES
BRAHMAPUTRA R.
Sadiya
Fort Hertz
Irrawaddy R.
Yang-tse R.
Mekong R.
Salween R.
Mitkyina
Minbu
Prome
RANGOON
Meping R.
BANGKOK
Mergui
Narcondam I.
Barren I.
92°
96°
100°
28°
24°
20°
16°
12°

Fig. 10.

rocks which were folded in the Upper Cretaceous and also subsequently in the Tertiary.

Two important overthrusts—the Naga and the Haflong-Disang thrusts—and several smaller thrusts and reversed faults are known on the Assam side of this arc. In all cases the thrust is directed from Burma towards India in a N.-W. or westerly direction.

Inside this arc, and parallel to it, is the main volcanic zone with Upper Tertiary to Recent Volcanoes—of the Jade mines area, Prome, Tharrawaddy, Barren Island, Narcondam—continuing into the volcanic zone of Sumatra, Java and other islands of the Indonesian archipelago. This zone lies at the faulted junction of the eastern border of the main Burma-Arakan range and the western border of the median Tertiary belt of Burma. Most of the volcanoes in this zone were active in Upper Miocene to Pleistocene times. (Chhibber, 1934, p. 284).

The next is the median Tertiary belt of Burma which contains the oil fields. The Tertiary gulf which occupied this area was gradually filled up by sediments which are of fresh to brackish water character in the north and marine in the south. There are stratigraphical breaks in Upper Eocene and Upper Miocene and a palaeontological break in Upper Oligocene. The Tertiary rocks are faulted against the more ancient rocks of the Shan plateau belt which lie to their east. In this fault zone is another line of volcanic rocks—the basic and intermediate lavas of Kabwet and Mandalay and the rhyolites of Thaton.

The Shan belt shows Pre-Cambrian, Palaeozoic and some Mesozoic rocks intruded into by Pre-Cambrian and Mesozoic (presumably Jurassic) granites. This granite belt passes through Bhamo and Mogok in the north and through Tenasserim into the Malay States in the south. The Shan belt is geologically allied to S.W. China and Indo-China.

## 3. The Baluchistan Arc

The Geological formations in Kashmir which have a general north-westerly trend, bend round sharply in the region southwest of Nanga Parbat. This deflection is particularly well seen northwest of Poonch, on the Kashmir-Hazara border (Wadia, 1931). It spreads out further south, a part going through Hazara into Safed Koh Mountains and Afghanistan and the other into the Sulaiman and Kirthar ranges of the Sind-Baluchistan border and into Mekran and Eastern and Southern Iran (Fig. 11). In contrast with the smooth-flowing broad curve of the Burmese arc, this shows three conspicuous festoons, because of the "gathering up" of the strata in the Dehra-Ismail Khan and Quetta regions The overthrust in this arc is from the northwest and west, and *towards India* as in the other cases. The festoons are evidently to be attributed

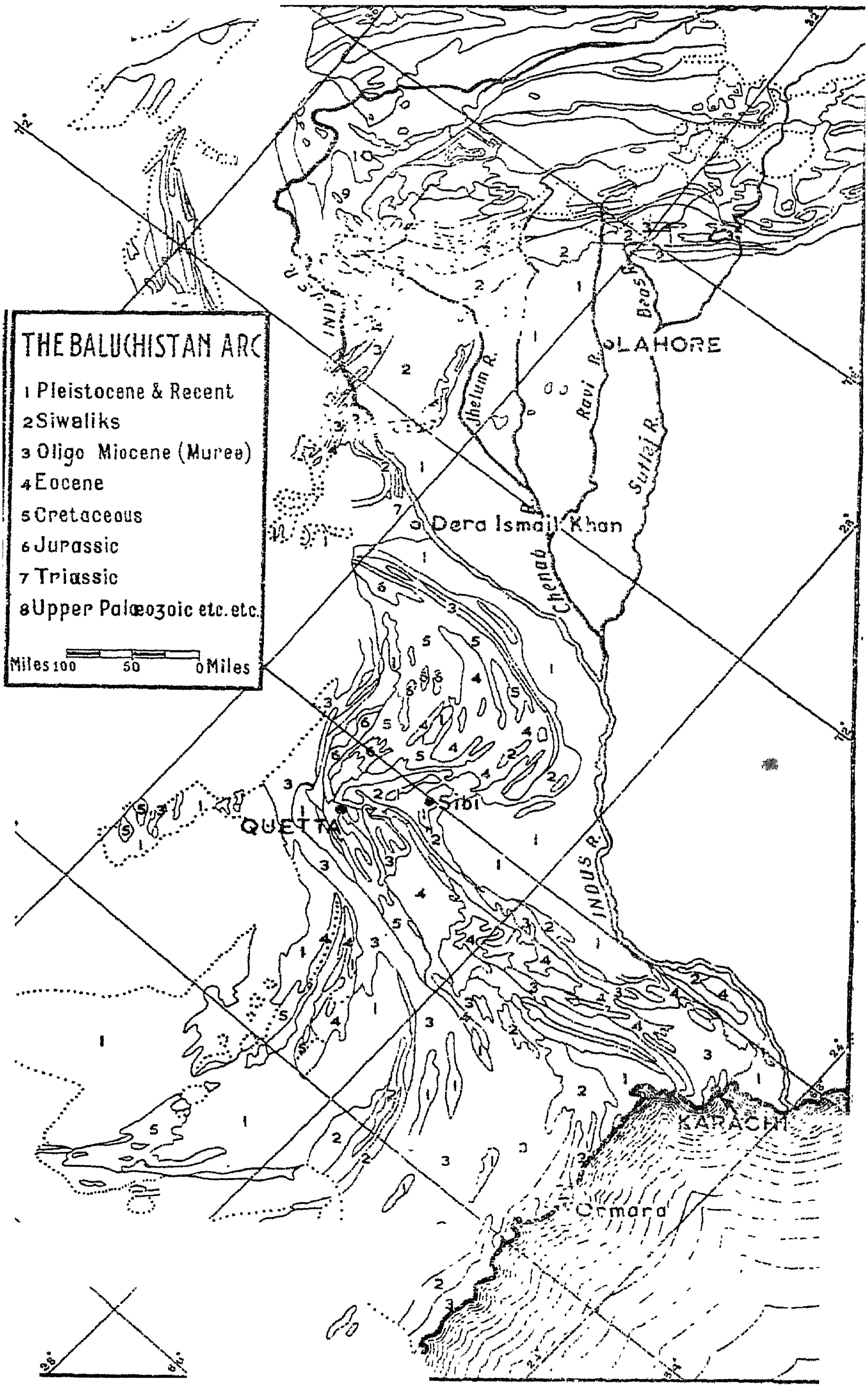

THE BALUCHISTAN ARC
1 Pleistocene & Recent
2 Siwaliks
3 Oligo Miocene (Muree)
4 Eocene
5 Cretaceous
6 Jurassic
7 Triassic
8 Upper Palæozoic etc. etc.
Miles 100 50 0 Miles
LAHORE
Jhelum R.
Ravi R.
Beas R.
Sutlej R.
Chenab
Dera Ismail Khan
Sibi
QUETTA
INDUS R.
KARACHI
Ormara

Fig. 11.

to the presence of wedges of ancient rocks, underlying the Indus alluvium, in the Dehra-Ismail Khan and Sibi-Quetta regions. On the convex side of the arcs lie the Murree (Oligo-Miocene) and Siwalik (Mio-Pleistocene) sediments, while on the cancave side lie Mesozoic sediments as well as Tertiaries of the *flysch* type.

In the north, in Hazara, two sedimentary facies lie side by side having a general south-west trend. The northwestern facies is of the Himalayan or Spiti type while the south-eastern (referred to frequently as the Calcareous zone) is a calcareous facies which continues into Sind-Baluchistan. The Calcareous zone in Sind-Baluchistan exposes Permo-Carboniferous, Upper Triassic, Jurassic, Cretaceous and Eocene rocks striking into the sea near Karachi, but soon after turning southwest towards Oman in Arabia. In this zone there are basic and ultrabasic intrusives as is the case in the Burmese arc.

South of Quetta and west of the Kirthar range, the formations spread out and turn westwards, going into Southern Iran. The Tertiary rocks here contain intermediate and basic volcanics as well as some volcanic cones which were active in the Upper Tertiary (one still active). This region seems to have been more highly folded and faulted than the corresponding Tertiary belt of Burma. The productive oil fields of Burma have survived apparently because that region has suffered less disturbance than Baluchistan.

## 4. Pre-Cambrian

The Pre-Cambrians of the Himalayas belong entirely to what was originally the northern border of India. They consist of an earlier group of gneisses and schists and a later group of metamorphosed sediments corresponding to the Delhis and Cuddapahs. In Kashmir they are called Salkhala series, Dogra Slates and Attock Slates; in the Simla-Garhwal region, the Jutogh and Chail series and Simla Slates; in the Darjeeling region, the Darjeeling and Daling series; in Bhutan, the Buxa series, etc. In the Darjeeling area, they abut against the plains without the intervention of a zone of Siwaliks which may be due to their being thrust further south over all the younger rocks during one of the late Tertiary movements (Heim, 1938; Heim and Gansser, 1939, pp. 5-6; Auden, 1949*a*, p. 330). The Himalayas to the south of the main range are to be regarded as part of the Peninsula, though their relationships are difficult to decipher because of the intense folding and overthrusting they have undergone.

Beyond the Central Himalayas, the Archaean and Pre-Cambrian are represented by the Vaikrita system (Griesbach, 1891, p. 41) consisting of schists, gneisses, limestones, quartzites, etc. and by the Martoli

Series (Heim and Gansser, 1939, p. 202) consisting mainly of quarzites and phyllites deposited as clays, sands and marl in a sinking geosynclinal basin and considered as of Algonkian age. The Martoli series represents part of the Haimanta system of Griesbach, and constitutes the well known peaks of Nanda Devi and Nanda Kot.

Archaean and Pre-Cambrian rocks in Burma are found in the Shan-Tenasserim belt, extending into S.W. China. It is not known whether the Archaeans in the Sadiya tract of Assam are continuous with those of Upper Burma or separated from them by a zone of sediments.

## 5. Cambrian

Cambrian strata are well developed in the Punjab Salt Range where they consist of purple ferruginous sandstones, shales and dolomitic sandstones. Saline marls with beds of salt and gypsum as well as some basic igneous rocks are associated with them. The fossils found include *Redlichia*, *Anomocare*, *Ptychoparia*, etc. The Cambrian development in the Baramula area of Kashmir and in the Spiti area of the Himalayas has also identical or closely related fossils.

In Spiti and Kumaon, Heim and Gansser (1939, pp. 202-203) state that the basal Cambrian is formed of the Ralam series (conglomerates, quartzites and massive yellow dolomite) followed by the Cambrian Garbyang series (slaty phyllites, dolomite and calcareous sandstones and shales containing trilobites and crinoids). The Garbyang series is equivalent to part of Griesbach's Haimanta system as shown by Hayden (1904).

Similar marine fauna with *Redlichia* and *Anomocare* is found in north-central and eastern Iran (Clapp, 1940). The Hormuz Series of the Persian Gulf region shows a great deal of resemblance to the Salt Range both in lithology and fossils. (de Bockh, Lees and Richardson—in Gregory, 1929).

No Cambrian strata have been found in Burma, but rocks of this age with *Redlichia* fauna is known in S.W. China (Eastern Yunnan, Szechuan and the Yangtse gorge). Upper Cambrian rocks are absent from here, but the sea transgressed again in the uppermost Cambrian, bringing in a fauna related to that of the Baltic region (Lee, 1939).

According to Du Toit (1937, p. 126), the *Redlichia* fauna of the Cambrian characterises a lengthy trough extending from Iran through the Himalaya into the Kimberley region of N.-W. Australia, South Australia and Tasmania, with an arm extending into Yunnan and Tonkin. This fauna had affinities to the North American fauna of the same age.

THE EXTRA-PENINSULAR REGION

## 6. Ordovician and Silurian

These two systems are well developed in Kashmir and Spiti, but not in the Salt Range where the Cambrian is overlain by the Talchir tillite. In the Himalayan Spiti area there is a thick succession of sandstones, shales and limestones of Ordovician and Lower Silurian ages, while the Upper Silurian forms part of the Muth Quartzite which is mainly of Devonian age. In the region of the Shiala Pass and the Dhauli valley there are calcareous sandstones, red crinoidal limestones and the 'Variegated series' (limestones, shales of varied colours) of these ages. The Variegated series occurs in the Zanskar range beyond Kumaon. The Himalayan fauna is rich in corals and brachiopods but devoid of graptolites. Rocks of these ages occur also in S.-W. Iran. In the Shan States of Burma, the Ordovician and Silurian are characterised by abundant graptolites, but few corals.

Ordovician strata containing graptolites and *Orthoceras* are found in Yunnan and S.W. China where there is a break in the Upper Ordovician and folding took place in Upper Silurian. The Burma and S.W. China fauna is closely allied to that of the Baltic region, while the Himalayan fauna shows affinities to that of N. America.

The Lower Palaeozoic is not represented in Malaya and the Indonesian archipelago. In Australia, the Cambrian sea moved eastward and the Ordovician and Silurian fauna is similar to that of S.-W. China and the Baltic. Orogenic disturbances took place at the end of the Ordovician and in Upper Silurian (David, 1950, pp. 168, 213).

## 7. Devonian

The characteristic formation of this period is the Muth Quartzite in the Western Himalayas in Spiti and Kashmir, where it consists of massive quartzite with intercalations of limestone, the quartzite being generally unfossiliferous. Limestones with brachiopods and corals are found along a more northerly zone in parts of Nepal, Spiti, Chitral, Afghanistan and Turkestan. In eastern and northern Iran, the Lower Devonian consists of red sandstones with gypsum while the Upper Devonian is marine, resembling the limestone facies of the Himalayan region.

In the Shan States of Burma, the Devonian is represented by the lower part of the 'Plateau Limestone'. Fossils have been found in two areas, one being a marine facies (Padaukpin limestone) with brachiopods and corals, and the other lagoonal (Wetwin Shales) with mollusca. The Devonian is also well developed in South China. The Middle Devonian (Eifelian) was a period of extensive marine transgression here and in Indo-China, and is characterised by *Calceola sandalina*

and *Spirifer tonkinensis*, and the Upper Devonian by *Spirifer verneuili* of the *Sinospirifer* group (Lee, 1939, pp. 121, 122, 124, 495).

The Devonian is well developed in Eastern Australia where volcanism persisted throughout. The Middle Devonian is marine and contains *Calceola* and *Stringocephalus*. In some areas plant beds containing *Lepidodendron* and *Cordaites* are found. The East Australian fauna is related to that of Dutch New Guinea, Indo-China, South China and Europe. The fauna of the Kimberley basin in West Australia has also European affinities, though the resemblance between it and that of Dutch New Guinea is not striking, which Teichert thinks may be due to difference of facies (David, 1950, p. 712). Teichert has recently recorded the presence of Middle and Upper Devonian and Carboniferous strata in the north-west basin of W. Australia (Teichert, 1949).

The barrier which separated the S.-W. China-Indo-China basin from the Himalayan basin in the Ordovician and Silurian seems to have disappeared, or largely so, in the Middle Devonian. The East and West Australian sedimentary basins were apparently connected to each other, though complete uniformity of fauna was not attained.

## 8. Carboniferous

The Lower Carboniferous in the Spiti area is represented by the marine Lipak series, while the corresponding formations in Kashmir are the Syringothyris Limestones. The overlying Po Series in Spiti is characterised by a *Rhacopteris* flora in the lower part (Lower to Middle Carboniferous), and marine strata with *Fenestella* and brachiopods in the upper part (Upper Carboniferous). This is paralleled in E. Australia where there was a great orogenic revolution in the Middle Carboniferous attended by effusion of lavas and intrusion of plutonic rocks.

The Upper Plateau Limestone in the Shan States of Burma shows a Permo-Carboniferous fauna with numerous brachiopods, *Fenestella* and Fusulinids, showing some affinity to the Himalayan and Salt Range regions. Marine Carboniferous strata are known in Sumatra, but the plant beds in Sumatra and Malaya contain a *Gigantopteris* flora, which shows that the land connection of these was with Indo-China and Cathaysia but not with India. In Sumatra and Central Borneo there is the Donau formation, consisting of radiolarian cherts and siliceous slates and much basic lava and pyroclastics. This formation is of Carboniferous and Permian age. In N.E. Iran also a fauna related to the Himalayan one is found, composed of brachiopods, corals and *Fenestella* in the lower and middle divisions, and Fusulinids in the Upper division.

There is a well-marked marine transgression in the Uralian (Upper Carboniferous) in many parts of the world. In the Himalayas this

transgression overlaps strata of all ages from the Cambrian to the Carboniferous, and particularly the Muth Quartzites. The Muth Quartzites are generally separated by a well marked gap from the following Productus (Kuling) Shales of Permian age. The transgression was caused by the Hercynian revolution. The Urals, Tien-Shan, Kun-Lun Karakoram, Nan-Shan, and possibly also Tsin-Lin, ranges came into existence at this time. In Ferghana, Mushketov (in Gregory, 1929, pp. 177-185) distinguishes an earlier Tien-Shan phase in the Middle to Upper Carboniferous, and a later phase in the Upper Permian. As a result of this Hercynian orogeny, a great latitudinal geosyncline was established, stretching from the Pyrenees and Alps to the Himalayas and possibly connecting through western Burma with the Banda part of the Indonesian archipelago (Timor-E. Celebes) to New Guinea and beyond Between West Sumatra and Timor, it should have lain to the south of the present chain of the larger islands. An arm of this apparently extended into Western Australia and another into the Tasman geosyncline which occupied Eastern Australia. This great Alpine-Himalayan geosyncline (the Tethys) persisted throughout the Mesozoic and was gradually dismembered during the Tertiary by the Himalayan orogeny. India at this time was part of Gondwanaland and lay much further to the south.

## 9. Permian

The transgressive marine Uralian passes upward into the Permian, the Uralian and the passage beds being often referred to as Permo-Carboniferous. As we have already seen, Uralian marine beds occur in Spiti and S.W. China. In the Salt Range, the Talchir tillite of Upper Carboniferous age is overlain by beds showing impressions of *Glossopteris* and spores of pteridosperms, and these by marine beds containing *Eurydesma* and *Fenestella*. These are followed by thin beds with *Conularia* and brachiopods. Similar Permo-Carboniferous beds are known in the Kolyma Province of Russia and also in Australia and South Africa. Another facies of these strata in the Salt Range is the Speckled Sandstone, though both the facies are often referred to as the 'Speckled Sandstone Group'. They are succeeded by the Productus Limestone Group, extending from the Artinskian to the uppermost Permian. The Productus Limestone facies is well developed in the Urals, Alps and Sicily.

In Kashmir, the Hercynian revolution brought about land conditions in some parts, and lavas and agglomerates (the Panjal volcanics) were erupted, commencing from the Upper Carboniferous and lasting up to the Upper Triassic. The pyroclastics are intercalated with slates containing a *Glossopteris* flora, fishes and amphibians. These Lower

Permian 'Agglomeratic Slates' are overlain in some areas by marine beds (Zewan beds) of Middle and Upper Permian age.

The marine Permian Productus Shales of Spiti continue eastwards. In the Mount Everest region and Sikkim, they are represented by the Lachi Series which is underlain by the Mt. Everest Limestone (so named as it occupies the peak) of Carboniferous to Permo-Carboniferous age. The Everest Pelitic Series below this is Carboniferous or earlier, and is profusely invaded by granite whose age has not been determined (Wager 1939).

In the Simla-Garhwal region south of the main Himalayan range the Blaini boulder beds are considered to be the equivalents of the Talchir tillites. They are overlain by the Infra-Krols (slaty shales and quartzites), the Krols (shales and limestones) and the Tals (shales and quartzites) which contain some indeterminable molluscan fossil fragments. These beds, which appear to have been laid down in shallow and perhaps land-locked waters near the margin of the Tethys, may represent the Permian and the Lower Mesozoic.

The uppermost part of the Plateau Limestone of the Shan States (Burma) contains Permo-Carboniferous fossils which are said to show some degree of affinity to those of the Salt Range.

Eastern Australia with its *Eurydesma* and *Conularia*-bearing beds shows close affinity to the Salt Range region only in the Permo-Carboniferous when the Tasman Geosyncline was connected with New Guinea. But the resemblance ceases from the Artinskian, probably because the geosyncline might have been cut off by a barrier in the region east of Queensland (David, 1950 p. 712). On the other hand, West Australian Permian fauna is more closely related to that of Timor, the Tethyan geosyncline and the Urals (David, 1950, pp. 374, 379, 398) than to the East Australian. According to Cowper Reed (1944), the affinities of the Salt Range fauna with the Russian Province became particularly strong from the Artinskian onwards but, mingled with the common fauna there is a local or endemic element in the Salt Range.

The rich marine Permian fossil assemblage of Timor, Letti, Tanimber, Ceram, Boeru and East Celebes (continuing into New Guinea) is closely allied to the Tethyan fauna. This geosynclinal belt, called the 'Banda geosyncline' by Umbgrove (1949, p. 36 and fig. 45), was in existence until the Laramide orogeny temporarily raised it up, after which, especially from the Oligocene onwards, the fauna became strongly Indo-Pacific, in common with Sumatra and Java. The Banda geosyncline was probably connected with the Tethyan through the border of Australia and through the Andamans and the Burmese arc, for there is little or no similarity in Mesozoic geology between the Banda arc and that to its

west which includes Sumatra, Java, etc. The earliest rocks seen in the Burmese arc (Axial system) are thought to be of Triassic age but we may expect the Permian also to be present underneath.

The Donau formation in Borneo, and its equivalents in Sumatra and Malaya, consist of radiolarites and volcanics (Pahang volcanics), occasionally intercalated with plant beds. Umbgrove (1949, p. 36) thinks that there were numerous volcanic islands in this region in the Permo-Trias and that the sediments were derived from the east or northeast. These volcanics extend from the Carboniferous to the Triassic. Marine Permian strata, though known to be represented in Malaya, are not wide-spread.

In South China, the Tsin-Lin geosyncline was compressed and folded in the earliest Permian. This was accompanied by lava flows in Yunnan and Kweichow. Several shallow basins came into existence and the Middle Permian shows coal seams with *Gigantopteris* flora. The marine facies, containing *Productus*, *Oldhamina*, *Lyttonia*, etc., has affinities with the Himalayan and Salt Range areas, the Upper Permian being rich in mollusca as in the Salt Range.

Coming now to the west of India, we find that in western Kashmir and Hazara there is a group of phyllites, quartzites and quartz-schists (the Tanawal series) overlying the Dogra Slates, and they may represent some part of the gap between the Cambrian and the Permian. They are overlain by the Tanakki boulder-bed which is followed by sandstones and shales and by 200 ft. of unfossiliferous massive limestones ("the Great Limestone"). This assemblage, called the Infra-Trias, is probably all of Permian age, especially as it is, in places, intercalated with the Panjal volcanics. To the south of the Salt Range, the Baluchistan arc contains some Permo-Carboniferous strata with *Productus* and other fossils.

Far down to the south, in Madagascar, we find tillites of Upper Carboniferous age followed by *Glossopteris*-bearing coal measures. There are no lower Palaeozoic rocks, as the tillites directly overlie Pre-Cambrian rocks. Above the coal measures are poorly fossiliferous Lower Permian rocks in the southwestern part of the island, but these are not represented in East Africa. The Lower Permian is succeeded, after a break, by the Upper Permian, which occurs on the mainland in the Tanga area and contains fossils which are common in the Salt Range. Since the rocks of Madagascar have a great resemblance to those of Kenya and Tanganyika, it is thought that Madagascar originally lay close to this part of East Africa. A rift between Madagascar and East Africa should therefore have developed in the Lower Permian, the sea invading this region from the north.

On the eastern side of Arabia and just south of the Persian Gulf is the Oman region, which is a structural unit alien to Arabia and belongs really to the South Persian basin of sedimentation. Suess considered the Oman ranges to be a virgation of the Zagros mountain system. Arabia (excepting Oman) is an ancient stable block practically free from mountain building movements since the Cambrian. It consists largely of gneissic rocks whose grain is roughly N-S or NNW-SSE as is also the case in Eritrea. On its west is the Red Sea rift which continues north into the Jordan Valley and the Dead Sea. This rift may have been formed in the Triassic or early Jurassic, for Triassic rocks are known in Eritrea and Jurassic rocks in the centre and along the southwest coast of Arabia. Roughly parallel to the Red Sea coast is the rift and sunken land of the Persian Gulf and the Euphrates Valley, which are of recent origin.

In the Oman region, there is only a small area exposing Cambrian rocks (Hormuz series) similar to those of the Salt Range. They are overlain by pre-Permian phyllites and by Permian, Jurassic, Cretaceous and Eocene sediments. All the rocks, up to and including the Lower Cretaceous, are invaded by the Semail igneous suite which are mostly basic in character, but include also serpentines, granites and diorites which must have been emplaced in the Middle Cretaceous (pre-Gosau or pre-Maestrichtian) according to De Bockh, Lees and Richardson (in Gregory, 1929).

The pre-Permian rocks of Oman contain limestones, shales and intercalated lavas, the associated fossils being indeterminable. On the southwest side there is a quartzite formation, also pre-Permian. These are succeeded by dark limestones of Permian age containing fossils closely related to those of the Middle Productus beds of the Salt Range. In Central Oman, there are sheared limestones containing a different fauna. These are followed by Triassic rocks.

In the Elburz mountain and Gulshan regions in Northern Iran Permian rocks having affinities with those of the Himalayan region are known (Clapp, 1940).

## 10. Triassic

The Triassic is well developed in the Spiti area and consists of the Chocolate series (Scythian), the Kalapani Limestone (Anisic, Ladinic, Carnic), Kuti Shales (Noric) and the Kioto Limestone (Rhaetic). The uppermost portion is a massive limestone (*Megalodon* or Kioto Limestone) which is mainly Rhaetic and partly Lower Liassic. The deposits in Kashmir are also similar.

In the Burmese arc the Triassic is represented by the lower part of the Axial system, which may be Upper Triassic. But these formations have not been investigated in any detail. In the Shan States there is a hiatus between the Plateau Limestone (Lower or Middle Permian) and the Rhaetic, which latter is characterised by shallow water deposits containing gastropods, lamellibranchs and corals. In the Red Basin of Szechuan, the Lower Triassic is a dolomitic limestone associated with rock-salt. But in Yunnan, marine fossils with Tethyan affinities are found. The sea receded in the Upper Triassic when mountain building movements affected China and Indo-China, Borneo and West Celebes.

In Malaya, Sumatra and Borneo, the Triassic includes marine deposits other than the radiolaria-bearing cherts. But a full succession with rich marine fauna of Tethyan affinities is developed in the Banda geosyncline. Triassic rocks have not so far been recorded from New Guinea. East Australia was a land of lakes during this period and the deposits contain a *Thinnfeldia* flora which replaced the *Glossopteris* flora more or less completely. In west Australia also, the geosyncline had receded to the west and land conditions prevailed.

In Kashmir, the full Triassic succession is met with in the Sind-Lidar valleys, central Ladakh and the Pir Panjal, but only the Upper Triassic is seen in the north-west and in Hazara. Here, the Lower Triassic is represented by the Panjal volcanics. Further south, in the Salt Range, the Lower Triassic and the lower part of the Middle Triassic are seen, but still further south, only the Upper Triassic is developed. In the Zhob-Pishin (Quetta) region of Baluchistan the Upper Triassic occupies an area 70 miles long (E-W) and 10 to 12 miles wide.

Except for local development of the marine Triassic, Madagascar shows mainly lacustrine and continental deposits (Isalo Sandstone). Land conditions prevailed also in parts of E. Africa, and in Central and South Africa. In may areas in Gondwanaland the Upper Triassic is transgressive over the Lower or Middle Triassic (Dixey, 1935), while the close of the period is characterised by extensive volcanism in the southern part of Africa.

In the Oman region of Arabia, Upper Triassic rocks overlie the Permian unconformably. They are composed of yellow sandstones, shales and thin limestones with mainly molluscan fossils. In S.W. Iran also the Triassic unconformably follows on the Permian, but the deposits contain a larger variety of fossils as in the Himalayas. In North Iran again, the Lower Triassic is missing and the Upper Triassic is a massive limestone characterised by brachiopods, gastronods and lamellibranchs (*Daonella*, *Pseudomonotis*, *Megalodon*, *etc.*), but few cephalopods recalling the conditions in the Himalayas,

The land conditions in the Lower Triassic, especially in the areas bordering the southern arm of the Tethys and in Madagascar and East Africa, indicate a marine regression probably resulting from the widening of the Arabian Sea-Mozambique Channel rift. This was followed by a transgression in the Upper Triassic.

## 11. Jurassic

In the Spiti area and N.W. Kumaon, the marine *Megalodon* Limestone continues without interruption into the Laptal series of Liassic age, characterised by layers of broken shells (lumachelle). This is overlain by a conspicuous oolitic bed of Callovian age known as the *Sulcacutus* bed which is a well-marked horizon, but the junction is marked by a discontinuity. The Callovian bed is followed by another discontinuity extending up to the Oxfordian or Kimmeridgian, when the 'Spiti Shales' began to be deposited. The same is the case in the Ladakh area of Kashmir also. In some places the Callovian unconformity extends up to the top of the Jurassic.

Jurassic rocks continue eastwards to Sikkim and occupy a large area in Tibet. On the Tibetan frontier of Kumaon (Punjab Himalaya), in the Chitichun—Kiogad area, there are large isolated masses of limestone resting on and surrounded by Cretaceous flysch sediments and andesitic and basaltic lavas and intrusives. These limestone blocks have yielded marine fossils of Permian, Triassic, Jurassic and Cretaceous ages and are of a facies different from that of the Spiti rocks, but closely resembling the Dachsteinkalk and the Hallstatt marble of the Eastern Alps. These are the 'exotic blocks' of Malla Johar described by Diener (1898) and by Von Krafft (1902). It is thought that these blocks were brought to their present position from the north either by floods of lava of Cretaceous age or by thrust-sheets or *nappes*. Heim states (1937, p. 445) that the 'exotic' region is the result of weathering of the thrust sheets derived from Tibet and that the Triassic rocks of the Kiogad peaks were noticed by him to extend for an unknown but large distance to the north-east. Heim and Gansser (1939, pp. 160-161) have given reasons to show that the exotic blocks and associated rocks are the remnants of great thrust-sheets which have travelled south-westwards from Tibet and include rocks of both Himalayan and Tibetan facies. The roots of these are in the similar zone of exotics of Darchen region south of Mount Kailas. In the Mt. Everest region, the facies is similar to that of Spiti; but in the Lesser Himalayas of Garhwal a part of the Infrakrol-Krol-Tal succession, which is either practically unfossiliferous or contains only fragmentary fossils, may be of Jurassic age.

The presence of Jurassic rocks has not been definitely recorded in the Barmese arc, but the Axial system and associated strata should

reasonably be expected to include these as they have been proved to contain both the Triassic and the Cretaceous.

The Namyau beds (red sandstones, shales and limestones) of Northern Shan States are of Bathonian age while the Loi-An beds of Southern Shan States contain Jurassic plants and coal seams. In Tenasserim on the Siam border, there are red sandstones, etc., lithologically similar to the Jurassic of Northern Shan States, Siam and Tonkin. The Shan area is connected through Yunnan to the Szechuan Red Basin near which fresh-water deposits with coal seams occur.

The end of the Jurassic was marked by the late Cimmerian orogenic activity in China, which raised up the Yen-Shan and Cathaysian ranges. It also affected Borneo, west Celebes and Malaya. The granites of Malaya, Tenasserim, Siam and Burma are generally assigned to this age (Scrivenor, 1931).

The Banda geosyncline as well as New Guinea show Jurassic rocks. In the latter, the Jurassic appears to be all post-Callovian.

In West Australia there are lacustrine sediments with plants of Rajmahal age. Marine transgressions occurred in the Middle Jurassic. A fauna of Tethyan affinities of Bajocian age has been found near Geraldton, and of Oxfordian age from boreholes at Broome (Teichert, 1940; 1947).

Coming now to the western side of the Tethyan geosyncline, we find two facies lying side by side in Hazara. The northwestern facies (the Kioto Limestone—Spiti Shale type) shows a break between the Bathonian and Oxfordian but the strata above the Oxfordian seem to be unfossiliferous until we come to the Albian (Cretaceous).

The Middle and Upper Jurassic are developed in the Salt Range. In the Samana Range, the Lower Jurassic is succeeded by the Upper Jurassic, with a break between the Callovian and the Oxfordian. In Eastern Baluchistan, the Liassic beds are succeeded by massive limestone which indicates deposition up to the Callovian. After this there is a break until the Neocomian.

Marine limestones and sandstones are seen in the Jaisalmer and Bikaner areas of Rajputana, ranging up from the Callovian. The full extent of these beds is not known, being partly hidden by desert sands.

In Cutch, on the western coast of India, there is a fine development of marine Jurassic strata ranging from the Bathonian to the top of the Jurassic and extending to the Aptian, with intercalations of plant beds of Neocomian age. It is thought that the basin of sedimentation deepened gradually as sedimentation went on. The fauna is rich in cephalopods, allied closely to those of the Salt Range and the Himalayas (Spath, 1933). Marine Jurassics are not exposed in central or western India though fluviatile and lacustrine Upper Gondwanas are found.

Jurassic sediments were laid down also at some places on the eastern coast of India where plant-bearing beds are associated with shallow-water marine beds. Some poorly preserved ammonites from these beds have been assigned a Neocomian age by Spath (1933, pp. 827-829). In the Rajmahal area, at the head of the Ganges delta, a few plant beds are associated with 2,000 ft. of basic lavas, while basic and ultrabasic dykes of the same age traverse the coal-bearing Barkars of the eastern coal-fields. Lava flows, presumed to be of the same age, are also seen in the Assam Plateau and in the Abor Hills in the Eastern Himalayas.

It will be clear, therefore, that the eastern coast of India definitely took shape sometime during the Jurassic period or towards its end, while the Cutch-Southern Rajputana region was inundated by the sea in the Bathonian and Callovian.

An interesting fact to which reference may be made is that, while there is a sedimentary break from the Callovian to the Oxfordian or Kimmeridgian in the Himalayas and in the Baluchistan arc, sedimentation commenced in Cutch in the Bathonian and proceeded uninterrupted until the Aptian. In Rajputana also, so far as known, there was sedimentation from the Callovian to the end of the Jurassic. Hence, in the Callovian, while the sea temporarily regressed from the margin of the main Tethyan basin, it transgressed over Rajputana and the western coast of India.

Jurassic rocks are well developed along the coast of Madagascar and East Africa and also in Somaliland, southern coast of Arabia and Central Arabia. In East Africa, however, they have not been found south of Lindi (Du Toit, 1937, p. 124) which probably shows that the Mozambique rift had not opened up beyond this in the Jurassic. The marine fauna of these areas is similar to that of Cutch. During the Middle Jurassic there was folding in Madagascar along a N-S axis, accompanied by faulting, which according to Du Toit (1937, pp. 123-124) was due to an anti-clockwise twist and movement of the island. The Rift Valleys of East Africa may have been formed also at this time.

In the Oman region, the Upper Triassic is overlain by the Mussandam Limestone, 5,000 ft. thick, containing Neocomian fossils at the top and therefore mainly of Jurassic age. In Southern Iran, the Lower Jurassic is non-marine but the Middle and Upper Jurassic are closely related to the strata of Cutch and the Salt Range.

## 12. Cretaceous

Cretaceous strata occupy large areas in the Himalayas and Tibet. In Spiti the Lower Cretaceous is represented by yellow glauconitic sand

stones and slaty quartzites called the Giumal Sandstone, the youngest part of which is Albian. They are overlain by the Chikkim series—grey and white limestones and shales—containing *Belemnites*, *Hippurites*, and foraminifera. Above these are flysch-type sediments. The Himalayan Cretaceous (especially the Lower and Middle Cretaceous) strata show evidence of a shallowing of the sea and a distinct change in fauna, because of the invasion of Mediterranean fauna probably through Syria and Southern Iran. The shallowing may be attributed to the withdrawal of water from the Tethyan basin to the Indian Ocean due to the breaking up of Gondwanaland and to mountain-building movements which took place during the Middle Cretaceous in parts of the Tethyan basin. There are no Tertiary strata known in the Spiti-Kumaon region.

In Malla Johar, Lower Cretaceous shales are overlain by flysch sediments. These include black flysch, red and green siliceous deposits and radiolarian oozes of late Cretaceous age, deposited in deep sea under geosynclinal conditions (Heim and Gansser, 1939, pp. 213-214). They are associated with volcanic breccia and some intrusions which are over 1,000 ft. thick, and in which huge blocks (exotic blocks) of fossiliferous marine rocks of all ages from the Permian to the Cretaceous lie pell-mell. These volcanics are of Upper Cretaceous age. Passing on to Kampa Dzong in Tibet, we find a full Cretaceous sequence, but it is not clear whether there is a break below the Cenomanian, for the pre-Cenomanian limestone is unfossiliferous. The Cenomanian and later strata are fossiliferous and pass upwards into the Eocene.

In the Burmese arc, Cenomanian and Upper Cretaceous fossils have been found both in the Axial System and in the Negrais series in the Arakan region. These include species of *Schloenbachia* and *Acanthoceras* characteristic of the Cretaceous of Trichinopoly, Madras. It is not known to what extent the Lower Cretaceous rocks are represented. At several places along this belt, peridotites and serpentines of Upper Cretaceous age are found—Jade Mines area, the Naga Hills, the Manipur Hills, Arakan region, and the Andaman-Nicobar Islands (*see* p. 74). *Orbitolina*-bearing limestones are found in Upper Burma while Upper Cretaceous red beds occur in Southern Shan States. Similar red beds are found in Szechuan in S-W China.

Malaya remained a land area during the Cretaceous while Borneo and Western Celebes contain Cretaceous sediments laid down during the Cenomanian and Senonian transgressions. Sumatra and Java also show Cretaceous rocks in some places.

The Banda geosynclinal belt continued to receive marine sediment throughout the Cretaceous. New Guinea also contains Cretaceous sediments, but it is not known whether any of these is younger than the Cenomanian (David, 1950, p. 670). The Banda geosyncline and New

Guinea were severely folded and raised temporarily above the sea in Laramide times. This movement affected also Sumatra and Java but the Borneo-West Celebes region lying to the north of the geosyncline was only mildly affected.

Marine beds are developed in West Australia from the Aptian onward and the fauna is closely allied to the Cretaceous of Trichinopoly in Madras, of Assam and of Madagascar. That is to say, the West Australian geosyncline was directly connected to the Bay of Bengal in the Aptian and the already weakening Tethyan faunal element was swamped by the Indian Ocean fauna.

Marine Cretaceous strata are found in the Trichinopoly district of Madras and on the Assam plateau. In the former, sedimentation began in Upper Albian and continued into the Eocene. On the Assam plateau the Cenomanian beds lie over the Archeans and they must originally have occupied a large area, as shown by the scattered outcrops. Beds with similar fauna occur also on the eastern and western coasts of Madagascar in Tanganyika and Mozambique. This sea extended southwards into Argentina. The occurrence of reptilian remains of closely allied species in India, Madagascar and Argentina indicates, according to Du Toit (1937, p. 124), that India and Madagascar were connected together until the Middle Cretaceous, for it is only in the Middle and Upper Cretaceous that marine sediments were laid down on the east coast of Madagascar. At about the same time, some Mediterranean faunal elements entered the Indian Ocean. India and Arabia then began to drift north-eastwards as a result of which the sediments of the Oman and Tethyan regions were subjected to folding in the Middle Cretaceous.

The north-eastern coast of Africa is marked by the Rivu-Mombasa and the Lindi-Mafia-Zanzibar faults which converge together (Du Toit, 1937, p. 125). As already indicated, they may have been developed gradually from the Upper Permian onwards. The dyke swarms of Eastern Madagascar and some of the volcanic rocks associated with the Rift system of E. Africa are thought to be of Cretaceous age.

In the Astor-Burzil region of Kashmir, Cretaceous sediments are intercalated with basic volcanics and intruded by serpentines, pyroxenites and granites. In the north-western zone of Hazara, there is a sedimentary break above the Albian and again at the base of the Eocene. The Calcareous zone (south-eastern) shows a similar break above the Albian but the break is said to continue into the Lower Eocene. This is repeated in the Salt Range where, however, Maestrichtian foraminifera have recently been found in strata which were regarded as Jurassic (Rao, S.R.N. and Tripathi, 1950). The unconformity in the Calcareous zone of Baluchistan may therefore be taken to extend from the Albian to the Senonian. The Cretaceous fauna includes *Inoceramus* and Rudistids,

indicating admixture with Mediterranean elements. The Upper Cretaceous is intercalated with basic volcanics and intruded by peridotites and serpentines with chromite deposits in the Hindubagh area near Quetta.

Cutch shows continuous marine sedimentation from the Jurassic up to the Aptian, after which there is a break, followed by the Deccan Trap flows, and these by Lower Eocene. In the Narbada Valley in Western India, Cretaceous strata begin only with the Cenomanian and continue into the Eocene. The fauna of these strata is more allied to that of Baluchistan and Arabia than to that of the eastern coast, though there are some common elements.

In Eastern and Northern Iran there is generally an unconformity in the Aptian-Cenomanian. An Aptian overlap is seen in South Central Iran and the strata from the Cenomanian upwards are mainly limestones containing Rudistids, Trigoniae, etc. The upper Cretaceous is characterised by lavas (rhyolites, porphyries and basalts) overlying the Hippurite limestone. These are followed by Maestrichtian and Eocene strata.

The Jurassic to Neocomian Mussandam Limestone of Oman is succeeded, after an unconformity, by strata of the Hawasina series consisting of sandstones, Rudistid limestones and red and green radiolarites associated with thick lava flows and intrusions of granite, diorite and peridotite (the igneous rocks being called the 'Semail group'). The Jurassic fauna of Arabia is related to that of Cutch and the Salt Range but not to that of Syria and Sinai; on the other hand, the Cretaceous fauna shows resemblances to the latter areas through which the Mediterranean elements must have entered the Indian Ocean.

The Oman region is highly folded and contains peaks as high as 10,000 ft. The range in the north runs NNW-SSE but turns south towards Masirah and Ras Madraka where the rocks run into the sea in a W.S.W. direction. The period of folding is pre-Maestrichtian (pre-Gosau) according to De Bockh and others (Gregory, 1929). There is little doubt that the rocks of the fold belt turn east and northeast after entering the sea, to join up with the Baluchistan ranges. The period of folding may be represented by the stratigraphical gap of the Aptian-Cenomanian which extended up to the Maestrichtian in Oman and to the Campanian in Beluchistan. It would appear that the folding movements continued into and affected the Baluchistan arc. As the Jurassic-Aptian succession in Cutch is also folded before the Deccan Traps were erupted late in the Upper Cretaceous, it might also have been folded at the same time—*i.e.*, in the Middle Cretaceous. That the Cretaceous folding movements affected the Baluchistan arc and even part of the Himalayan Tethyan basin finds support in the presence of Upper Cretaceous ultrabasic and other igneous rocks at some places in Baluchistan, Kashmir and the belts of exotic blocks of Kumaon and Tibet.

On the other side of India, in the Burmese and Banda arcs and in New Guinea, mountain building took place in Laramide times, when the Burma-Assam sea was divided into two gulfs separated by the newly risen Assam-Arakan ridge. The Middle Cretaceous movement in the Baluchistan arc and part of the Tethyan basin in the Himalayas should therefore be treated as the earliest of the Himalayan movements which had full play in the Tertiary. In accordance with the theory of Continental Drift, the Middle Cretaceous should be the time when the north-eastward drifting India encountered and began to crumple up the Tethyan geosynclinal basin.

It has already been stated that the Oman region does not belong to the Arabian mass but is really a geosynclinal area subjected to mountain building movements in the Cretaceous epoch. Arabia was severed from Africa probably in the Upper Triassic, since Liassic sediments are known along the southern coast of Arabia. In its north-easterly drift, Arabia encountered the Oman basin, just as the Indian shield came up against the Tethyan basin. The Cutch-Narbada valley area was a minor basin, on the border of India, which also suffered folding as a result of the same drift.

## 13. The Deccan Traps*

The Deccan Traps now occupy some 200,000 sq. miles and must have formerly covered a more extensive tract, probably twice the present area. They are regarded as having been erupted from numerous fissures in the crust during a period of tension. They are estimated to have a thickness of over 6,000 ft. near the Western Coast (Oldham, 1893, p. 262), but much less in other areas. They must originally have extended also for an unknown distance to the west of India but that part was faulted down in or about the Miocene.

Geologists in India generally include the basic lavas on the Sind-Baluchistan border with the Deccan Traps, but as they are in the fold-belt of the Baluchistan arc and occur as intercalations in Upper Cretaceous strata, it would be better to exclude them from the Deccan Traps proper.

In Cutch, Kathiawar and Gujarat, the Traps appear to be of the uppermost Cretaceous to the earliest Eocene age. In Cutch, where they are 2,500 ft. thick (Wynne, 1872, p. 60), they have been exposed to sub-aerial weathering and denudation, with the alteration of the topmost layers to laterite before the Nummulitic Laki Series (Upper division of Lower Eocene) was deposited over them. Blanford (1869, p. 62) has stated that near Tarkeser in Broach (Gujrat) there is an unconformity between the Traps and the Lower Eocene, and that the latter contains pebbles and detritus derived from the former (Oldham, 1893, p. 282).

* The Deccan Traps, confined to the Peninsular region, are discussed here for descriptive convenience.

In the rest of the area occupied by the Traps, they are considered to be of Eocene age from the study of plants, fishes and foraminifera found in the Inter-trappean sedimentary beds (B. Sahni, 1940 ; Hora, 1938).

There are several eruptive centres in Kathiawar and the Narbada Valley, from most of which acid volcanics have been erupted while two of them contributed plutonic intrusives also. They are roughly aligned ENE—WSW in the Narbada Valley but the line connecting the centres curves towards the WNW in Kathiawar. The age of these eruptions must be later than that of the main mass of the Traps.

Dyke clusters are confined mainly to two rectilinear zones—one along the Panvel flexure parallel to Bombay coast, and the other along and parallel to the Narbada rift—and to an elliptical area around Amreli in east-central Kathiawar. The first two are connected with fold or fracture zones while the third is supposed to be a domed up area in which peripheral and radial fractures played an important part in the formation of dykes. They have been described recently by Auden (1949). The dykes are mostly later than the Traps though there must be many, in these and other areas, which acted as feeders to the Trap flows.

The Traps were erupted and spread over an uneven pre-existing topography. Their base is now found at different levels above or below sea level : at 2,000 ft. above sea level at Belgaum ; 1,000 ft. near Nagpur ; at 1,600 ft. on the flanks of the Maikal range ; at 2,500 ft. south of Sohagpur and in the Ranchi Plateau ; and at or over 3,000 ft. in Jashpur (Auden 1949, p. 321).

But at some places near Bombay, in the Narbada Valley and in Kathiawar, their base lies 500 to 1,800 ft. or more below sea-level, as a result of folding and faulting.

They lie with a profound unconformity on all pre-existing rocks and sometorne their margin may be seen transgressing over a series of formations as in Southern Rajputana, Central India, south of Pachmarhi and Sohagpur, etc. They must originally have extended at least as far east as East Longitude 85°. In some areas, the Gondwanas over which they lie have been folded before they were erupted and it is possible that the period of folding was the Middle Cretaceous which affected the Cutch area and which possibly extended into the Narbada-Son Valley.

The Traps have themselves suffered folding and faulting at a later date. Gentle warping has been noted in the Traps of Chindwara by Fermor and Fox (1916, p. 81). In Rajpipla in Gujarat, at the western end of the Satpura mountains, the Traps are sharply folded along ENE—WSW axis and dips of 20° have been noted (Blanford, 1869, p. 57). Folding is well seen along a zone bordering the Narbada Valley in the Central Provinces (Crookshank, 1936, p. 265, etc.). The Panvel flexure,

which extends from Panvel (18°59′ : 73°07′) to Kalyan near Bombay in a S-N direction and then turns NNW to the coast near Daman, is a monocline, the western limb of which dips at 10° into the sea. In south-eastern Kathiawar the Traps show dips of 10° towards the southeast while in Cutch they have been folded into well marked anticlines and synclines. In most other areas the flows are practically horizontal. The period of folding may be either the end of the Eocene or the Middle Miocene.

Faults are known to have affected the Traps in some places. The south side of the Narbada rift has been faulted down some thousands of feet (Crookshank, 1936, pp. 261, 265, 286) in relation to the Traps on the Pachmarhi side. The Ellichpur fault running by the side of the Gawilgarh Hills shows a downthrow of a minimum of 1,800 ft. and a maximum of perhaps 4,000 ft. (Fermor, 1930, p. 409). There is a post-Trap fault to the north of the Satpuras of the Pachmarbi area (Crookshank 1936, pp. 276, 287). The Bombay coast is itself a fault scarp of probably Miocene age, the downfaulting being of the order of 6,000—7,000 ft. The different faults may have originated at different times.

The Aravallis must have been cut across along the Narbada region (and probably across to Cutch) in the Middle or Upper Carboniferous, thereby enabling an arm of the sea to reach Umaria in Lower Permian times. This remained a zone of weakness afterwards, for folding and faulting continued to affect it until geologically recent times. The basin of the Purna tributary of the Tapti shows Pleistocene sediments containing salt water to a depth of at least 120 ft. which is thought to be due to the sea extending here during the Pleistocene (Oldham, 1893, p. 401).

## 14. Eocene

The Tertiaries of the Himalayan region can be divided into three periods of sedimentation, each culminating in an orogenic movement. The three periods are the Eocene, Oligocene to Middle Miocene and Upper Miocene to Pliocene. The corresponding formations are the Eocene, the Murree and the Siwalik. The orogenic activities at the end of each of these periods are generally referred to respectively as the first, second and third phases of Himalayan upheaval. There is reason to believe that there was an earlier movement in the Middle or Upper Cretaceous as mentioned already, and later movements in the Pleistocene and sub-Recent times (De Terra, 1936). The history of the Burmese Tertiary is roughly similar to that of the Western Himalaya, but a difference is discernible in the Assam Tertiaries formed in the gulf which existed to the west of the Burmese arc. In Assam, the Barail and Jaintia series extends from early Eocene (or even Upper Cretaceous)

to the Middle Oligocene, when a wide-spread unconformity occurs. The succeeding Surma series and Tipam series are roughly Oligocene to Lower Miocene and Middle Miocene to Upper Miocene, respectively. A second important unconformity occurs in the Upper Miocene, succeeded by the coarse sediments of the Dihing Series of Pliocene age.

The Eocene comprises three distinct facies—a deep sea facies in the Calcareous zone of Baluchistan, Northern Kashmir and the Tibetan zone of the Himalayas (which extended at least as far east as the meridian of Lhasa in Lower Eocene), and also in parts of the Burmese arc; a shallow facies on the southern side of the main Himalayan range as far east as Naini Tal and in Cutch, Gujarat, S.W. Rajputana, and the southern border of the Assam plateau; a *flysch* facies in parts of the Himalayas and in Baluchistan. There was also a fresh water facies in N.W. Punjab and in Upper Burma.

The Laramide orogeny raised the East Indian archipelago (particularly the Banda arc) and New Guinea into land temporarily and land connection was probably established between S.E. Asia and Australia for a short time. The sea transgressed again over this arc and over Western Celebes and parts of Borneo in Lower Eocene. There was still a strong Tethyan element in the fauna of the East Indies and New Guinea during the Eocene (David, 1950, p. 709). But at the end of the Eocene, the Tethyan element disappeared and the Indo-Pacific fauna, which was already prominent in Madras, Assam, Madagascar and W. Australia in the Cretaceous, established itself in the East Indies and New Guinea basins.

In Oman, both fossiliferous marine facies and the *flysch* facies are developed in the Eocene, the fauna of the former being similar to that of Baluchistan. The Eocene extends into and occupies a large area in Central Arabia. In Eastern and South-eastern Persia there are thick basic volcanics, pyroclastics and some intrusives commencing from the Middle Eocene and continuing into the Oligocene. The marine fauna closely resembles that of Baluchistan. In S.W. Iran the Lower Eocene is of shallow origin, characterised by red marls and gypsum.

## 15. Oligocene—Lower Miocene

The orogeny at the end of the Eocene broke up the Tethyan geosyncline into shallow basins. The Baluchistan and Burma areas were however, connected with each other through the Indian ocean and fossiliferous open-sea sediments as well as those of the *flysch* type continued to be deposited therein. On the southern side of the Himalayas, the Murree System of brackish water sandstones was deposited in the

Punjab and Kashmir and for some distance further east. Marine deposits were also formed in Southern Cutch and in Gujarat.

In southern and south-western Iran, the Oligocene is represented by the Asmari Limestone (marine) and the Fars Series (lagoonal), the latter showing deposits of saline marl, gypsum and anhydrite. In Arabia, the Oligocene and Miocene are developed in restricted areas and are of shallow facies.

There was sedimentation in the East Indies all along the outer arc (Nias-Mentawei strip and the Banda geosyncline) as well as in parts of Sumatra, Java, East Celebes and Borneo. The fauna is Indo-Pacific in character.

## 16. Middle Miocene—Pliocene

Towards Middle Miocene, intense orogenic forces affected the Himalayan, Baluchistan and Burma arcs and considerable uplift and thrusting took place. Granites, and possibly also other igneous rocks were extensively intruded along the main Himalayan belt.

The unconformity below the Middle Miocene (Miocene—e4, of Umbgrove, 1949, p. 40) seen in many areas in the East Indies is probably the effect of the Himalayan orogeny. In Upper Miocene (Miocene—f2) intense folding and thrusting took place in Southern Sumatra and the inner arc, as well as the entire outer arc, and especially in the Banda geosyncline and New Guinea (Umbgrove, 1949, p. 41, fig. 50). The overfolding and thrusting came from the north in the Banda arc and from N. E. in New Guinea.

The deposits of this period are found all along the foot-hills of the Himalayas, in Potwar and Jammu areas, in Sind, in the Burmese Tertiary belt and on the Assam side of the Burma arc. They constitute the Siwalik System and its equivalents which are generally composed of coarse fluviatile sediments. Their great thickness (of the order of 16,000-18,000 ft.) along the border of the Himalayas shows that they were formed in a shallow depression which was gradually sinking, the recently risen mountains being the source of the sediments.

The Siwaliks were folded and thrust over by older rocks, probably at the end of the Pliocene; in their front, along the margin of India, a fore-deep went on forming. This fore-deep is now the valley of the Ganges and Brahmaputra, filled with thick Mio-Pliocene, Pleistocene and Recent sediments. Movements of some magnitude took place also in the Pleistocene, for we find that the Karewas of Kashmir have been raised up several thousands of feet on the slopes of the Pir Panjal and that certain beds enclosing Palaeolithic remains have been tilted and lifted to a height of 4,500 ft. (de Terra, 1937).

Marine Mio-Pliocene rocks are found in Baluchistan, on the east and west coasts of India, in northern Ceylon and in the Arakan area. The fauna is similar to that of Java and other islands of the East Indies.

In Eastern and Southern Iran, the Upper Miocene and Pliocene beds are represented by the Upper Fars and Bakhtiari beds which are shallow water deposits, the latter resembling the Siwaliks. The Middle Pliocene is highly folded, and the eroded Bakhtiari beds are overridden by nappes which may be of Upper Pliocene or Pleistocene age.

The Upper Tertiaries in Arabia were gently folded in Upper Miocene or Pliocene and subjected to faulting and uplift. Along the Oman coast, downfaulting occurred probably in Pliocene or later, because of which the trend of the formations is abruptly truncated. The northward projection in Oman on the Persian Gulf Coast and the corresponding kink on Iranian side of the same Gulf is due to an extension of the Oman Range into Iran. Rocks of the Hawasina series are found in a few places in the Zindan nappe north-east of Bandar Abbas. The Oman folding (Cretaceous), however, affected the South Persian geosyncline very little, and in any case the full Tertiary succession in Southern Persia has obscured a good deal of the previous structures present there. This geosyncline began to develop in the Jurassic and therefore most of the deposits are later than the Middle Cretaceous Oman orogeny. In this area, the autochthonous belt is followed, to the north, by an 80-mile-wide nappe zone containing three nappes, which successively bring up older rocks over the younger. The overthrusts are directed from the north-east towards the south-west. An uplift is known to have occurred in pre-Maestrichtian, probably during the Oman orogeny, for there are thick Maestrichtian conglomerates here. The Miocene is transgressive over older rocks. The Mid-Miocene Bakhtiari beds were uplifted and eroded before the violent folding of the Pliocene, which was probably continued into the Pleistocene. Finally, the folded rocks were elevated and the Persian Gulf-Euphrates Valley region depressed or faulted down. This may be of the nature of a 'fore-deep' between the Arabian mass and the Tertiary fold-belt of the Zagros mountain system. The northern shore of the Persian Gulf shows fault scarps of Pleistocene or Post-Pleistocene age in several places. (De Bockh and others; in Gregory, 1929.)

## MOVEMENTS IN INDIA DURING THE TERTIARY

It is generally recognised that after the Jurassic there was an uplift and erosion before the Cenomanian transgression took place. The period of uplift may be just after the Neocomian. The Cretaceous sedimentation apparently continued into the Eocene, as Eocene foraminifera have been recorded from the Pondicherry area. In Gujarat and Cutch, the Laki Series (Lower Eocene) is found to be transgressive over the Cretaceous. There was again a well marked transgression in or about the Middle Miocene, especially along the southwestern, and all along the eastern, coast. Minor epeirogenic oscillations have occurred in the Pliocene and Pleistocene times also, as evidences are found in raised beaches, submerged coasts, etc.

The Assam plateau is considered to be a *horst* uplifted in the Miocene. It is bordered on the north by a fault showing a prominent scarp. On the southern side, the western portion is a fault which, when followed eastward, becomes a monocline and further on merges into the Haflong-Disang thrust fault with overthrust from the Burma side, this thrust fault continuing in a north-easterly direction into Upper Assam. There are several parallel thrust zones in the Patkoi-Naga-Manipur-Lushai Hills which represent thrust movements from the Oligocene or Miocene onwards. The western side of the Assam plateau may also be marked by fracturing which may be connected with the Garo-Rajmahal gap through which the Ganges and the Brahmaputra now flow southwards to sea.

The Himalayan orogeny produced a 'fore deep', a down-buckling of the crust to form a trough in front of the folded mountains. The various stages of the movement would have accentuated this basin. It would appear that the southern arm or flank of this synclinal trough suffered elevation at each stage. Four regional uplifts have been noted in Chota Nagpur, Bihar, which are, according to Dunn (1939, p. 141) :—

1. Lower Tertiary uplift of 1,000 ft.
2. Middle Tertiary (Mid-Miocene ?) uplift of 1,000 ft.
3. A further uplift of 300 ft.
4. A still later uplift of 400 ft.

The total uplift was therefore of the order of 2,500-2,700 ft. This is best seen in the Ranchi plateau along North Latitude 23°. But it is interesting to note that along latitude 25° there was practically no

movement, this being of the nature of a hinge zone located somewhere in the middle of the southern limb of the trough. The movements are shown diagramatically below. (Fig. 12).

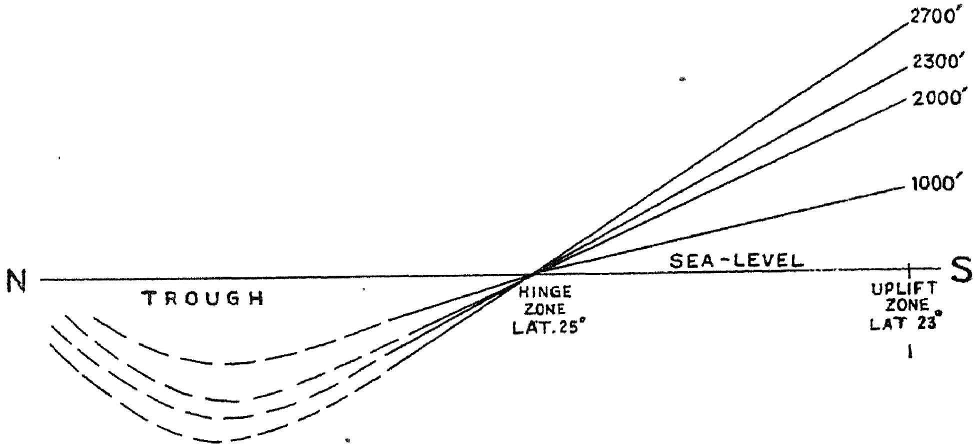



Fig. 12.

## THE EASTERN COAST AND THE BAY OF BENGAL

The eastern coast in Orissa and northern Madras down to the Kistna Valley is parallel to the Eastern Ghats. Then it turns south, accommodating itself roughly to the Archaean and Cuddapah rocks which here show southerly to SSE trend a little to the north of Madras. The coast more or less maintains its southerly trend, with a slight easterly convexity in the Nellore region, up to the Cauvery delta, though the rocks turn sharply towards the S. W. and WSW near Madras city. In the southernmost part of the Peninsula, the coast has a south-westerly trend down to Cape Comorin, but here it is practically perpendicular to the strike of the rocks.

The earliest marine sedimentary rocks along this coast after the Cuddapah-Vindhyan times occur in the Middle or Upper Jurassic amongst the Upper Gondwana rocks of Guntur and Kistna districts. Though similar plant-bearing upper Gondwanas are known to occur in Orissa and Southern Madras, they do not seem to be associated with any marine intercalations. Neither are marine strata associated with the Tabbowa beds of the north-west of Ceylon. It is, therefore, clear that the eastern coast of India took shape during the Jurassic.

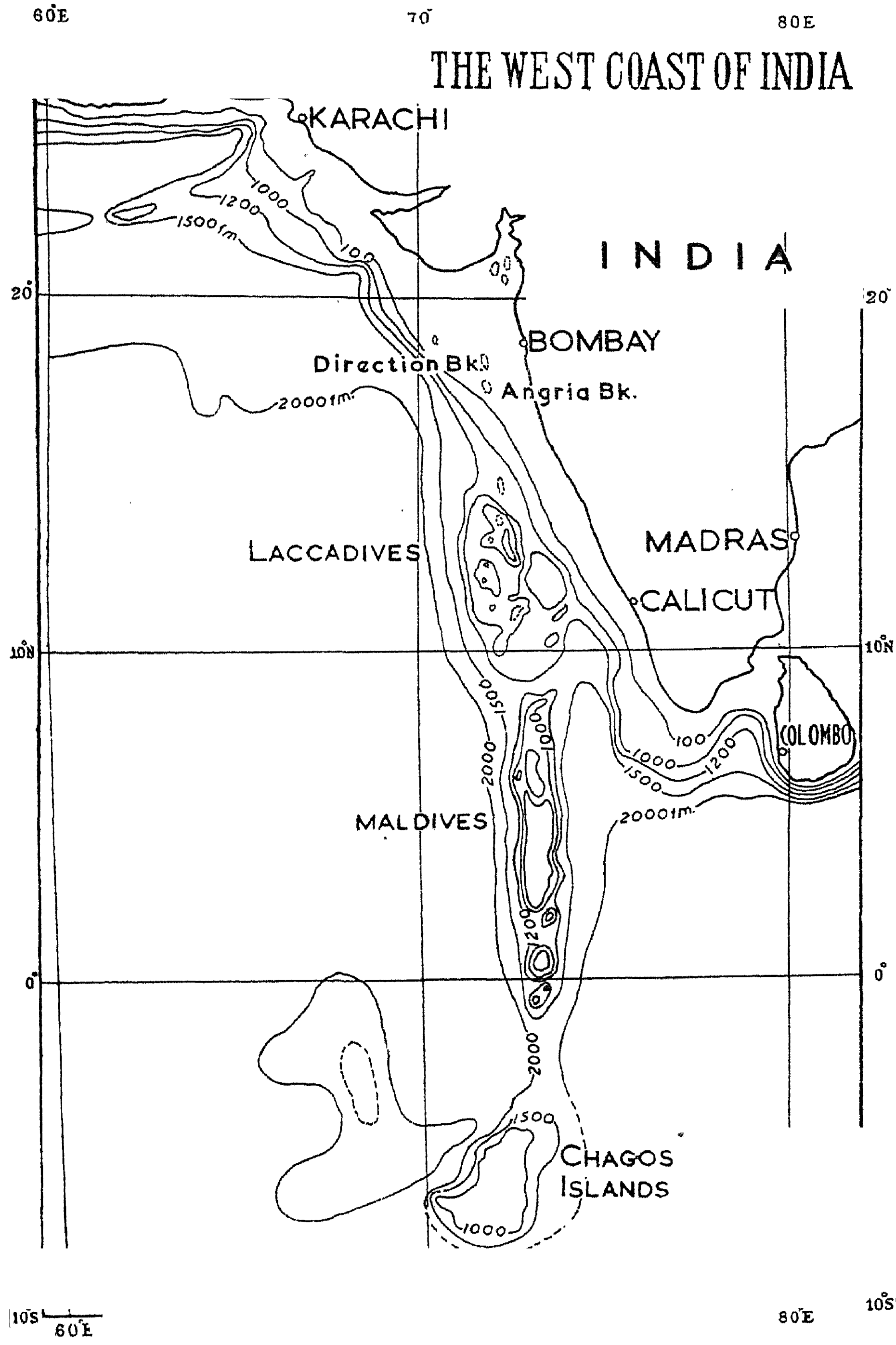
The West Australian geosyncline seems to have been formed in the Devonian. The incipient Bay of Bengal of Jurassic times was probably directly connected with it, since evidence of such direct connection is available in the Cenomanian fauna being very similar in both the Trichinopoly area in Madras and in the West Australian geosyncline. The Upper Cretaceous fauna of Madagascar and East Africa are also similar so that we can assume that, at that time, the Indian Ocean lapped the shores of all these lands. Ceylon seems to have been first severed from India in the Middle or Upper Miocene for it is only at that time that marine beds (Jaffna beds) were formed on the north-west and north of Ceylon (Jacob, 1949, p. 341). Thereafte· connection and severance took place a few times, and the sea separating the two is very shallow and supports numerous coral islands.

Proceeding now to the eastern part of the Bay of Bengal, we have already seen that the sea extended, in the Cretaceous, over a 'arge part of Assam and Burma. A ridge was raised up by the Laramide orogeny along what is now the axis of the Burma arc and the two arms thus created were gradually filled up during the Tertiary. The connection of the Burmese sea with the Himalayan one probably ceased about this time or, at any rate, at the end of the Eocene.

It would thus appear that the Andaman Sea (*i.e.,* the basin between the Burma-Andaman-Sumatra arc and Tenasserim-Malaya) took shape at the end of the Cretaceous (Sewell, 1925). The eastern border of this basin is regular and is marked by the submerged ridge bordering the Mergui Archipelago. The Andaman Sea basin connects with the Sunda Sea through a channel coursing through the Straits of Malacca. Sewell has suggested that this channel may be a drowned river valley. The western border is less regular and consists of a mountain chain 700 miles long, a few peaks of which rise above sea level. The mountain chain is really the Andaman-Nicobar part of the Burma-Sumatra arc and it shows Cretaceous and early Tertiary sediments (and recent coral limestone) with some serpentine intrusions (Tipper, 1911). The basin was probably a shallow sea originally, but faulted down later to its present depth. It now consists of a main basin, 2,000 fathoms deep at its deepest part, and two subsidiary basins to its north-west, each 1,000 fathoms deep. The main basin is separated from the smaller by the volcanic ridge on which Barren Island is situated. This ridge runs first to the north-east from Little Andaman Island and then north to join the zone of volcanoes in Burma. Southwards, it joins up with the volcano zone of Sumatra. To the west of and close to the Andaman ridge is a subsidiary submarine ridge which, according to Sewell, continues into the Nias-Mentawei ridge south of Sumatra (on the axis of the major negative gravity anomaly strip—Umbgrove, 1949, plate X). Whatever may be the significance of the ridge said to occur west of the Andamans, there is little doubt that the Andaman-Nicobar ridge runs directly into the Nias-Mentawei ridge. There is another submerged ridge (Carpenter's ridge) about 30° west of the Andaman ridge, and separated from it by a gulley called the 'Investigator deep'. According to Tipper, (1911, p. 210) the Andaman ridge is overfolded to the west. The existence of a much wider shelf on the western side of the Andaman ridge than on its eastern is explained by Sewell as due to the progressive eastward shift of the anticlinal axis of the fold, following the suggestion of Brouwer's. The Tenasserim Coast of the Andaman basin, on the other hand, is only moderately faulted. The Shan plateau of Burma which is the northern continuation of Tenasserim, shows a fault scarp on its west along which it is said to be overthrust westwards. It is, therefore, probable that Tenasserim is also similarly uplifted and thrust over to the west.

Submarine contours of the Western Coast of India show that the margin of the continental shelf is remarkably straight from near Cape Comorin to the West of Kathiawar. This lends support to the deduction, from other data, that this coast was faulted down in comparatively recent times. Leaving aside the Gujarat-Narbada Valley zone, which is known to be an ancient zone of weakness, the only marine strata found on this coast are of Lower Miocene age forming a narrow coastal strip in Travancore (Eames, 1950, pp. 236, 239). The Deccan traps near the Bombay coast are over 6,000 ft. thick, becoming gradually thinner eastwards. They show a slight dip towards the sea near Bombay, this being due to the Panvel flexure trending roughly parallel to the coast. It is clear that they could not have stopped abruptly at the coast with such a thickness but must really have extended further west. The western extension has been faulted down into the sea. Between Ratnagiri and north of Bombay there is a series of hot springs along a straight line parallel to the coast, which show that they are located on a line of fracture. This also lends support to the coast being a faulted zone. The age of the fault, as indicated above, is about the Lower Miocene (Oldham 1893, p. 495) or slightly earlier.

The Continental Shelf is limited roughly by the 100-fathom line (Fig. 13). The shelf is generally 25 to 35 miles wide but is widest near about N. Lat. 20°. It slopes gradually over this width and then rapidly down to about 1,000 fathoms. Making an acute angle with the coast and the shelf, is the Laccadive-Maldive ridge which is thought to be the continuation of one of the main Aravalli ridges. It is very likely that the Chagos Archipelago also belongs to that ridge. From the southern end of the Chagos to the northern end of the Laccadives, the distance is 1,500 miles. All these groups of islands rise from platforms which are about 1,200-1,300 fathoms deep. The Chagos Islands are separated from the Maldives by a channel which is about 2 degrees wide and 1,600-1,700 fathoms deep. The Maldive group is separated from the Laccadives by a much narrower channel about 1,200-1,300 fathoms deep. Followed northwards, the Laccadive ridge continues up to Coradiva island, between which and India there is a narrow gap 1,066 fathoms deep. A bank called the 'Adas Bank' was formerly reported to exist in this gap but Sewell (1935) doubts whether it exists. But along the trend of the Laccadive ridge we find two banks on the continental shelf, the southern being the 'Angria Bank' and the northern the 'Direction Bank'. They lead northward, through the Gulf of Cambay, to the Aravalli mountain chains. The idea that these banks represent a continuation of the Aravallis receives indirect support from the fact that a strip of strong positive gravity anomalies runs along it, into the Lacca-




g. 13. (After R. B. S. Sewell.)

dives. The Maldives, however, lie in a zone of negative anomalies which at its northern end turns in the direction of Cochin on the west coast of India. It may also be noted that the general alignment of the Maldives is slightly to the east of that of Laccadives, while that of the Chagos is distinctly to the west of the Maldives alignment.

Sewell (1935, p. 426) has called attention to the fact that the Elicalpeni Bank in the south-eastern part of the Laccadive group is separated only by a narrow channel from Malabar and that its position is on the westward continuation of the Eastern Ghats in the Nilgiri region. If there is any truth in this suggestion, it would mean that the Eastern Ghats continued right up to the (supposed) extension of the Aravallis into the Laccadives.

The Kirthar Range, which forms more or less the boundary between Sind and Baluchistan in Pakistan, runs down to Cape Monze near Karachi where it is covered by the sea. The same strata as those near Cape Monze are found in a small island called Churna which lies to the west of Cape Monze (Oldham 1893, p. 312). This feature is seen to continue south-westwards as a well marked submarine ridge (called the Murray Ridge). It rises from the bottom of the sea 1,700-1,800 fathoms below sea level. To its south-east is a gully 2,100 fathoms deep which, when followed in a south-westerly direction, first shows a tendency to shallow to 1,600 fathoms and then resumes its original depth.

About 1° Latitude south of the Murray Ridge is another ridge. At about co-ordinates 10° 20′ N. : 64° 0′ E., it shows a peak which is only 440 fathoms deep, but in general the top of this ridge is about 1,500 fathoms below sea level. It has been traced as far west as 20° N : 61° E. It is not clear whether these two ridges strike into the Oman Coast.

The strip of sea adjoining Mekran (Baluchistan) is streaked with numerous straight parallel ridges which are part of the Zagros mountain system. The sea here gradually deepens to 1,800 fathoms at which depth the bottom is practically flat. The ridges generally rise to heights of 2,500 to 3,000 ft. above the sea floor. Some of the ridges are at a distance of 60 miles from the Mekran Coast.

Since Middle Miocene rocks have been involved in the downfaulting of the Mekran sea, the date of faulting may be late Miocene or Pliocene. It may be that the western coast of India was faulted down in Lower Miocene and the faulting extended into the Mekran region somewhat later. Further extension of this faulting into the Persian Gulf and the Euphrates valley apparently occurred in the Pleistocene.

From the Island of Socotra near the north-eastern tip of Africa, there runs the Carlsberg Ridge system, in a south-easterly and then southerly

direction to Rodrigues (Fig. 14). It is a broad arc convex to the east, rising from the ocean floor at a depth of 2,300 fathoms. The basins on either side are over 2,700 fathoms deep. Concentric to this is another arc, on which are situated the island groups of Seychelles, Saya de Malha,

BATHYMETRIC CHART OF THE INDIAN OCEAN

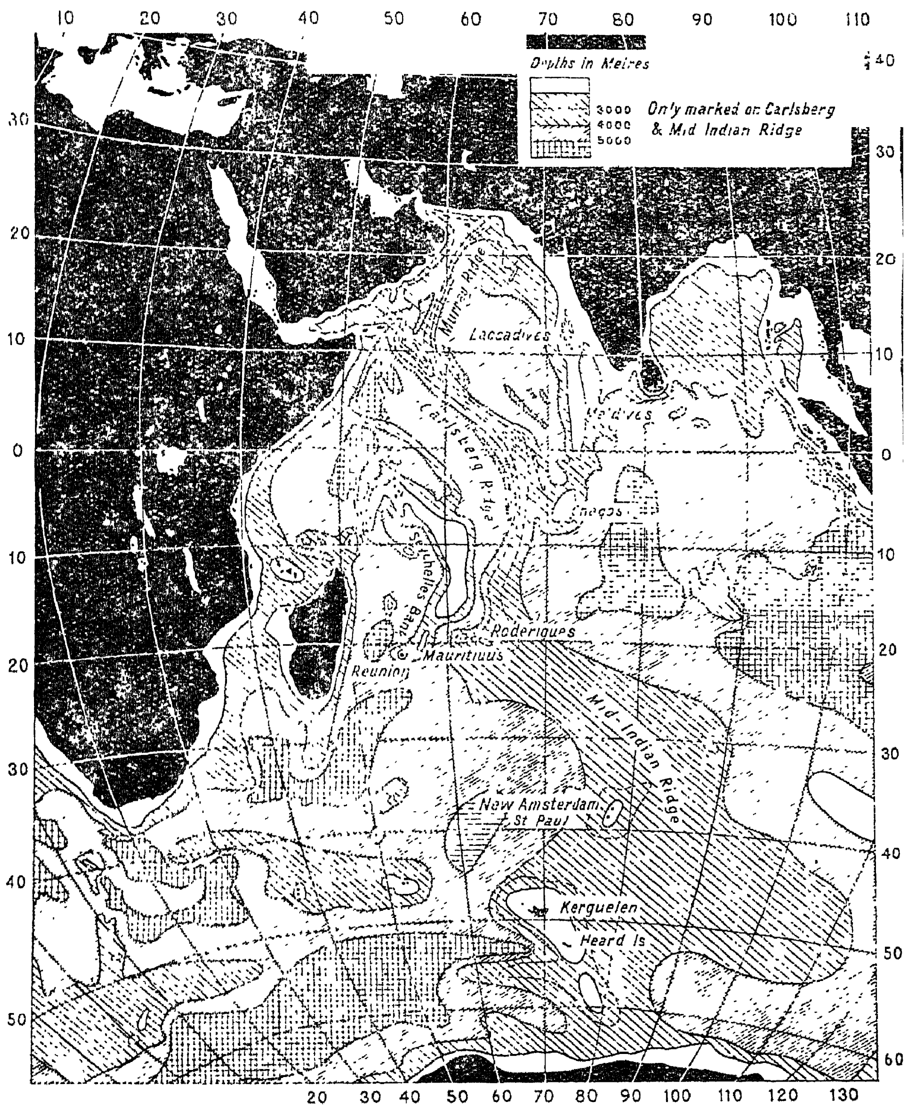



Fig. 14. (After I. D. H. Wiseman and R. B. S. Sewell.)

Nazereth Bank and Mauritius, and on the concave side of which lies Madagascar. Wiseman and Sewell 1937) are of the opinion that the ridge system in the Indian Ocean and the East African rift system

have a considerable degree of similarity and that they form a mirror image of each other along 50°E. meridian. Some of the samples of rock dredged from the surface or sides of the submerged ridges were found to be basalts. This ridge system lies roughly midway between India and Africa and is similar to the Mid-Atlantic ridge between Eur-Africa and the Americas. The origin of the Mid-Atlantic ridge has been explained by different authors in different ways. The Atlantic and Indian Ocean basins are surrounded by markedly fractured coasts and it is therefore reasonable to assume that the ridge systems are due to effects of tension in the respective basins. After Gondwanaland was fractured, the parts drifted apart. The fractured coastal regions would then be loaded with sediments derived from adjacent land, with consequential rising or bulging up of the central strip along which igneous material from the basaltic layer would rise to form a ridge. As the continental masses on either side drifted, adjustment would take place in the mid-ridge by lateral and vertical movements (Du Toit 1937, pp. 217-219, 226-227). The phenomenon would be a sort of the reverse of what happens in a zone of compression connected with a geosyncline, where the sial crust is downfolded, followed by uplift of the sediments in the geosyncline and igneous intrusions, mainly granitic, from below. In this case, the thin sial crust would bulge up and be broken through by basaltic magma from below.

# ULTRAMAFIC ROCKS AND OROGENIC BELTS

There are numerous scattered references to occurrences of ultramafic rocks in various parts of India. A general sorting out of these occurrences shows that they fall in one or the other of the known belts of mountain building. When these were plotted on maps the above-mentioned connection was clearly brought out, as will be seen in Figs. 10 and 15 to 17. The writer is obliged to his colleague Mr. N. A. Vemban for carrying out this task of collecting information and plotting the occurrences. An attempt is here made to present only the easily available information, and it is possible that more exhaustive search will reveal other occurrences in these and certain other areas.

The occurrences brought together here include what have been described as peridotites, dunites, saxonites, lherzolites, serpentines and pyroxenites, which in most cases are associated with such alteration products as asbestos, talc, serpentine, and magnesite. Some amphibolites have been included, as it was not clear whether they were derived from pyroxenites or from basaltic rocks.

## 1. Rajputana

The occurrences in this area mentioned below, are arranged from north to south (Fig. 15).

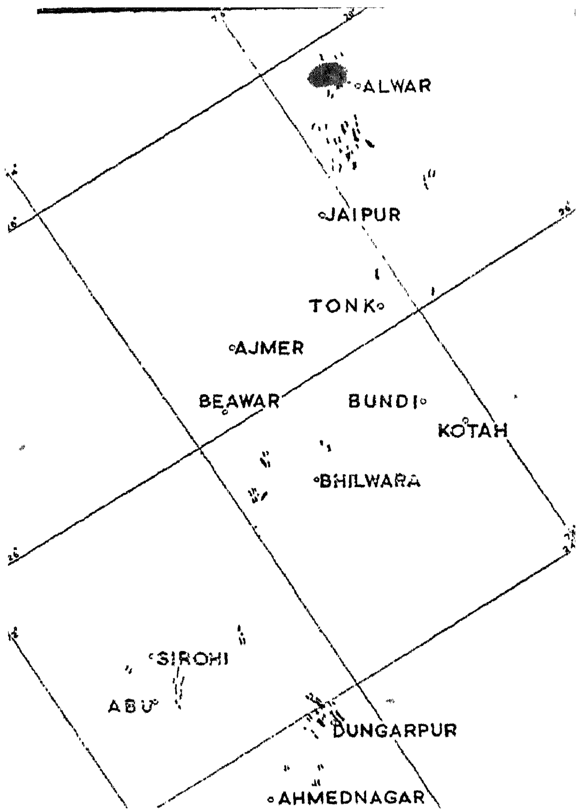
Numerous lens-like masses and thick sills of amphibolite are found folded in with the Delhi System (Alwar Series) from near Mandarwar (27° 52′ : 76° 36′) to Jhiri (27° 14′ : 76° 16′) and Raialo (27° 5′ : 76° 17′). They seem to be mainly altered basaltic rocks (Heron, 1917).

Steatitic rocks are found in several places in the Biana-Lalsot Hills (Heron, 1917*a*, p. 200) especially near Maroli (26° 46′ : 76° 34′) and Morra (26° 49′ : 76° 52′). The occurrence of Nawai Hill (26° 22′ : 75° 59′) is also of the same nature (Heron, 1922, p. 391). In Central Mewar, B. C. Gupta (1934, p. 124, 156) has recorded the presence of amphibolites in pre-Aravalli and Aravalli rocks near Idra (24° 36′ : 74° 16′), Bhilwara (25° 21′ : 74° 39′) and other places. Talc and chlorite-bearing rocks derived from ultramafics, and serpentines with magnetite are found near Beawar and to the south of Ajmer.

Talc-serpentine rocks occur intermittently along a NNE-SSW zone between Kanhat (24° 23′ : 73° 29′) and Sempala (24° 49′ : 73° 37′) north-east of Udaipur city, according to P. K. Ghosh (1933, p. 449-460). Coulson (1933) has described amphibolites of Delhi and post-Delhi ages from several localities in Sirohi, between Pundwara (28° 48′ : 73° 3′) and Rohera (24° 37′ : 72° 58′). Talc-serpentine-chlorite rocks are developed near Rikhab Deo (24° 5′ : 73° 41′), Kherwara (23° 59′ :

73° 36′) and east of Dungarpur (23° 50′ : 73° 40′), etc. Some of the exposures are large and up to 60 ft. in thickness and their trend is N-S to NNW-SSE (Ghosh, 1933).

Serpentine, chrysotile and steatite occur in several places in Idar according to Middlemiss (1921, pp. 99-109), as for example near Dev Mori (23° 40′ : 73° 28′), Ghanta (23° 36′ : 73° 16′), Kokapar (23° 31′ :




OCCURRENCES OF AMPHIBOLITES
AND
ULTRABASIC ROCKS IN RAJPUTANA

Fig. 15.

73° 28′) and Thurawas (23° 43′ : 73° 16′). Some of these are more than a mile long and up to 300 ft. thick.

Plate 4 shows that all the above occurrences fall in the Aravalli-Delhi belt in which there was orogenic activity in post-Aravalli and post-Delhi times. In Dungarpur and Idar the arrangement of the exposures is N-S or NNW-SSE, following the change of strike of the axis of the folds.

## 2. Mysore

Coming now to the Mysore region, we find that there is a variety of altered and metamorphosed basic and ultrabasic rocks in all the Dharwarian exposures, and especially in the southern parts of the Shimoga and Chitaldrug belts where the rocks have undergone high grade metamorphism. It is likely that the southern part of the state exposes more deeply eroded sections than the northern part (Fig. 16).

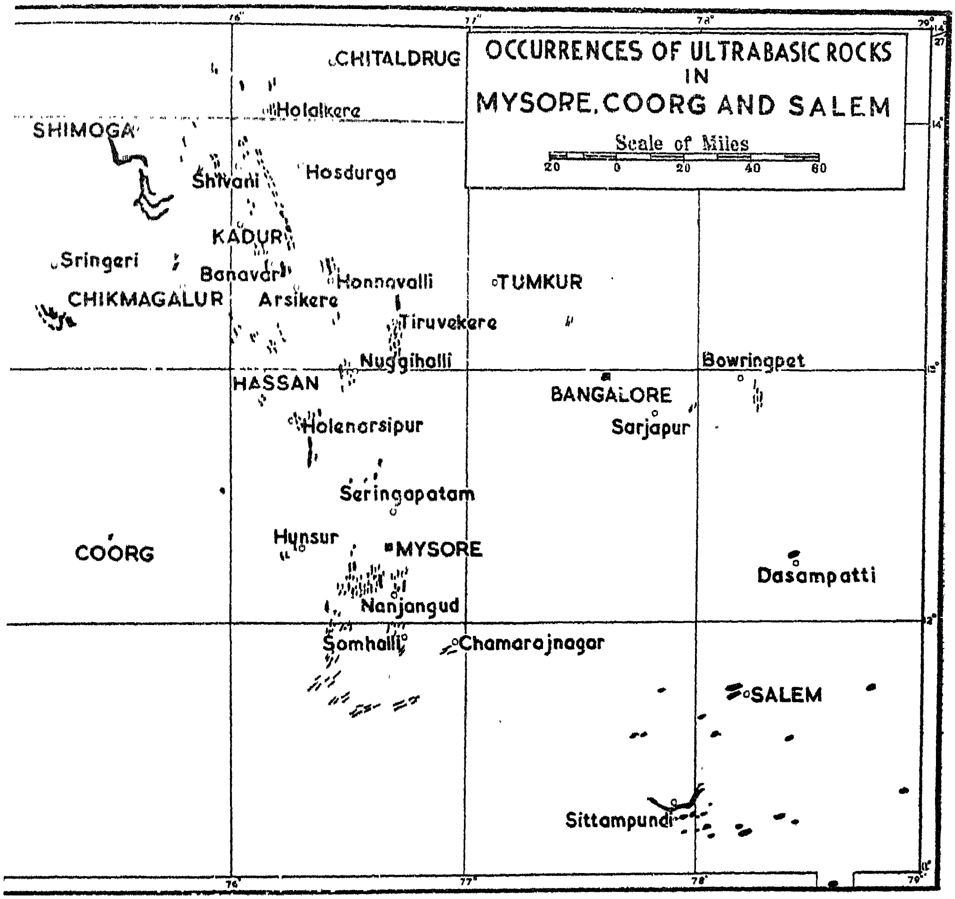



Fig. 16.

Partly altered peridotites and pyroxenites are found in numerous places in the Shimoga and Kadur areas *e.g.* near Jajur (14° 8′ : 76° 1′), Sulikere (14° 9′ : 75° 55′), Holalkere (14 2′ : 76° 13′), Jhandimatti (13° 58′: 75° 51′), Hiriyur (13° 48′ : 75° 46′) Lakkavalli (14° 32′ : 75° 41′) etc. In the Hassan district, serpentine and steatite rocks are associated with amphibo'ites. There are also pyroxenites, enstatite-tremolite rocks and olivine-bearing rocks near Hassan (13° 0′ : 76° 8′), Holenarsipur (12° 48′: 76° 17′), Honnavalli (13° 20′: 76° 27′),

Tiruvekere (13° 10′ : 76° 44′), Nuggihalli (13° 0′: 76° 3′) etc. To the south and south-west of Mysore city, there are numerous bands of hypersthenites associated with charnockites. They are particularly abundant between Mysore city and Nanjangud (12° 7′ : 76° 43′). Peridotitic rocks also occur further south along the same belt near Sargur (12° 0′ : 76° 23′), Hoskote (11° 53′ : 76° 27′) and Rampur (11° 45′ : 76° 27′).

In following the exposures from north to south it is seen that they are confined to the Dharwarian belts and that at the southern end near Mysore the strike becomes N-S, finally assuming further south a NNE-SSW trend, that of the Eastern Ghats here. The details for Mysore have been taken from several papers by E. W. Wetherell, M. K. Slater, P. Sampat Iyengar and B. Jayaram in the Records of the Mysore Geological Department.

## 3. The Eastern Ghats

As we have already seen, the portion from South Malabar and Nilgiris to Madras (through Coimbatore, Salem and Arcot) is dominated by the Eastern Ghats trend which has a ENE-WSW direction first, and later a NNE to NE direction. Several exposures of dunite and related rocks, mostly converted to magnesite, steatite and asbestos, occur in Salem (Krishnan, 1951). These are also shown in the south-eastern part of the map of the Mysore region (Fig. 16). The ENE trend of the occurrences is very clearly seen in the map. Some of the exposures are fairly large, the ' Chalk Hills ' area near Salem being 6 sq. miles in two closely spaced patches. Passing through Sittampundi (11° 15′ : 77° 54′) there are also bands of chromite- and corundum-bearing pyroxenite, amphibolite and anorthosite, shown by a curved branching line in the map.

The Eastern Ghats belt, throughout its length, shows large masses of charnockite which include patches of ultrabasic composition (hypersthenite, enstatitite and pyroxenite) in many places. One such patch near Kondapalle (16° 37′ : 80° 32′ ) contains small but workable deposits of chromite. Another deposit of chromite occurs at Nausahi (21° 17′: 86° 20′) near Bhadrak in Orissa in peridotitic rock intrusive into ancient gneisses. Charnockitic rocks are, however, by no means confined to this belt, for they are known to occur in the Dharwarians and in the gneisses of southern Mysore, Travancore and Tinnevelly and also in Ceylon, East Africa, Antarctica and Western and Central Australia. But it is not known whether they are all connected with orogenic belts.

## 4. Satpura Belt

It is only for the Singhbhum area in this belt that data are readily available regarding the occurrence of ultrabasic rocks (Fig. 17). According-

ing to J. A. Dunn (1929, p. 96; 1939, p. 50, 143, 236) the ultrabasics were intruded in the main shear zone of the Singhbhum copper belt just after overthrusting took place, but in some cases they have also been affected by folding and dislocation.

To the north of the large area of Dalma volcanics, some distance north of the main shear zone corresponding to the Singhbhum Copper Belt, there is an E-W zone showing sills of pyroxenite in sheared phyllitic

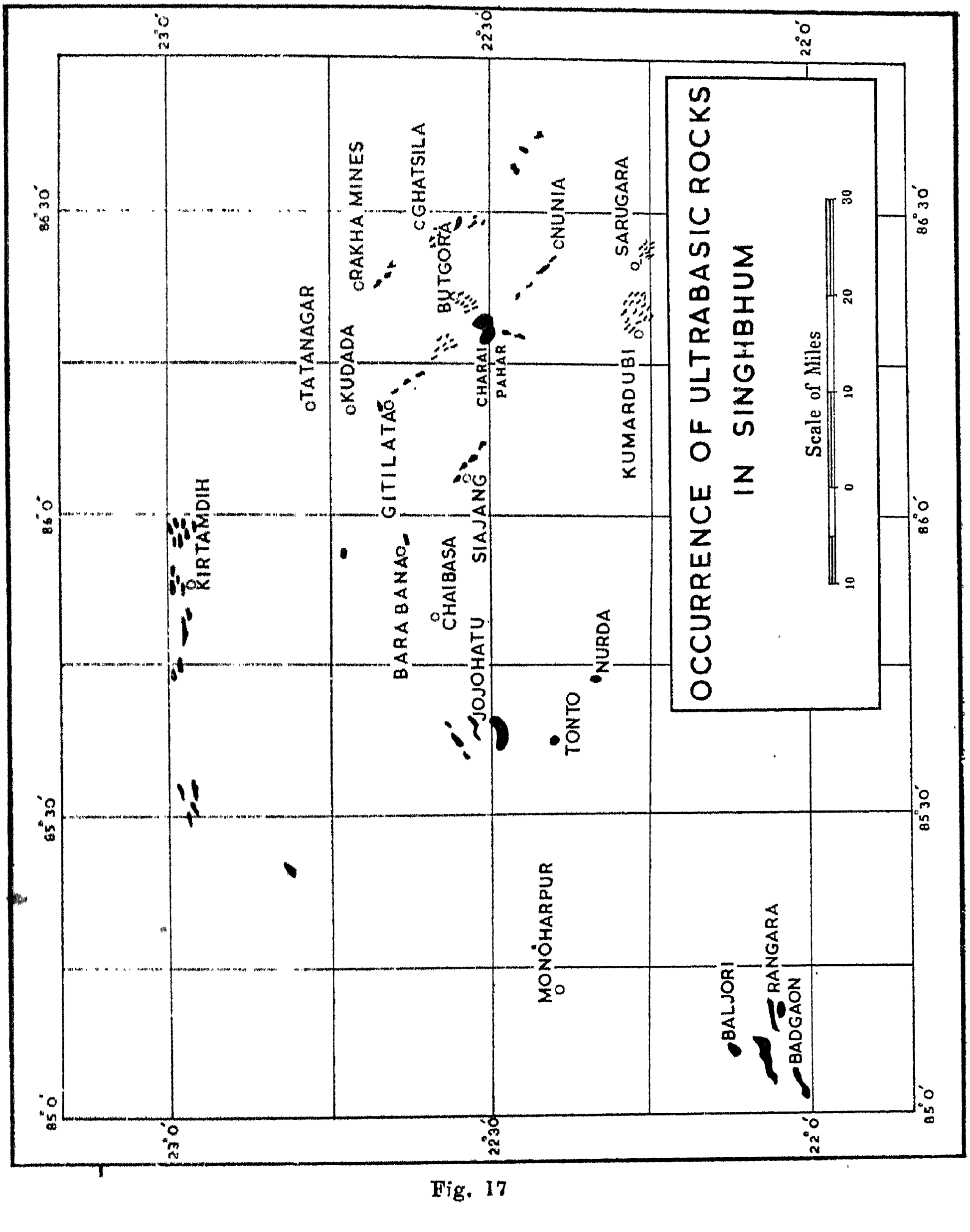



Fig. 17

rocks. These are seen near Kirtamdih (21° 58′ : 85° 51′), Chunadih (21° 59′ : 85° 57′), etc.

To the south and east of Tatanagar, the basic and ultrabasic rocks appear in three or four zones which are more or less parallel to the main shear zone. The easternmost extends from Rakha Mines (22° 40′ : 86° 12′) to Mahulisol (22° 28′ : 86° 34′) and beyond. The occurrence at Kudada (22° 42′ : 86° 12′) may probably belong to this zone. A second zone passes through Gitilata (22° 40′ : 86° 12′), Manpur (22° 36′ : 86° 16′) and Butgora (22° 33′ : 86° 20′). The next includes the large mass of Charai Pahar near Dublabera (22° 29′ : 86° 17′) and a series of small exposures from Lakaidih (22° 26′ : 86° 18′) to Nunia (22° 23′ : 86° 25′). A fourth zone is indicated by occurrences near Bara Bana (22° 27′ : 85° 56′) which possibly connects with Siajang (22° 33′ : 86° 4′). Along the south-eastern extension of this are the large masses of Kumardubi (22° 17′ : 86° 19′) and Sarugara (22° 16′ : 86° 24′) which are basic rocks containing numerous lenses and patches of serpentine and magnetite. The Batgora mass is similar to these.

In addition to the above, there are a few large isolated masses of olivine-bearing rocks (saxonites, lherzolites, pyroxenites, etc.) at the following places (Jones, 1934, p. 217) : Jojohatu (22° 31′ : 85° 38′) comprising three large masses, each several hundred feet thick and containing chromite deposits ; Tonto (22° 23′ : 85° 37′) ; Nurda 22° 20′ : 84° 44′) containing highly serpentinised rocks ; Nangalkata (22° 5′ : 85° 5′), a large laccolith nearly 4 miles long ; Badgaon (22° 2′ : 85° 2′) ; Baljori (22° 5′ : 85° 4′) ; and Rangra (22° 3′ : 85° 9′). These masses are not connected with the shear zones, but appear to be aligned parallel to the Eastern Ghats strike (NNE-SSW) characterising the area in which they occur.

## 5. The Tertiary Mountain Belt

We have already seen that the orogenic belt of Oman is intimately associated with the Semail igneous suite comprising basic and ultrabasic igneous rocks as well as granites and diorites. The zone of the most intense folding corresponds to the zone of deep sea sediments including radiolarites (Picard, 1937, p. 419 ; Davis, 1950). The Oman ranges very probably extend into the submarine ridge which is a continuation of the Kirthar ranges of Sind.

The Jurassics and later sediments of Cutch are folded along a E.-W. or N. W.-S. E. axis. There are two lines of 'trap' intrusions, one in Cutch and the other in Patcham and other islands in the Rann. As no modern work has been done on these intrusives it is not known whether they consist entirely of Deccan Trap flows or whether they contain also patches of ultramafic rocks. Wynne (1872) mentions the presence of

coarse augitic rocks in western Cutch which may or may not include pyroxenites and peridotites.

The Baluchistan arc shows sills and intercalations of basic rocks in Upper Cretaceous and Eocene sediments, but the only well-known occurrence of peridotitic rocks seems to be the group near Hindu Bagh ENE of Quetta, which is associated with large chromite deposits which have been worked for about forty years. Similar deposits have come to light recently in the area north of Fort Sandeman along the continuation of the same belt. These are considered to be of Upper Cretaceous age.

Basic and ultrabasic rocks of Cretaceous age are also known in the Burzil-Dras area of Ladakh north of the main Himalayan Range of Kashmir (Wadia, 1937, p. 154). The ultrabasic rocks are serpentinised peridotites, said to contain much associated chromite, extending NW-SE over a length of several miles.

Serpentinised ultrabasic rocks are found in the 'exotic block' region of Balchdhura and Kiogad in the Kumaon Himalaya. They occupy the Balchdhura heights (18,110 ft.) and some localities along the pass of that name (Heim and Gansser, 1939, pp. 149-164). Similar rocks are known in the region north of Balchdhura, near Jangbwa, south and south-west of Lake Manasarowar, and in the Darchen area south of Mount Kailas. These ophiolitic rocks are considered by Heim and Gansser (1939, pp. 173, 180-189) as younger than the Cretaceous *flysch* sediments with which they are associated. They also point out (pp. 162-163) that the igneous rocks occur with and are intrusive into deep-sea deposits —radiolarites and siliceous sediments—which indicate a possible Upper Cretaceous or early Eocene age. Granitic rocks are intrusive into the Central Himalayas as well as in the Trans-Himalaya range. The intrusion of the ultrabasic rocks should have taken place during the first orogenic upheaval of the Himalaya, *i.e.*, in the Upper Cretaceous (de Terra, 1936, p. 864), more or less contemporaneous with the Oman orogeny.

There is little information on the occurrence of ultrabasic rocks along or near the axis of the main Himalayan range in Nepal and Eastern Himalayas, though it is known to be intruded by large batholithic masses of granite almost throughout its length. More detailed work along this belt in future may bring to light some occurrences.

Numerous occurrences of peridotite and serpentine, some of which are associated with jadeite and others with steatite, are known in the Burmese arc. They are all thought to be of Upper Cretaceous age (Fig. 10).

According to Chhibber (1934*a*, pp. 24, 32) serpentinised peridotite associated with jadeite occurs near Tawmaw (25° 41′ : 96° 15′); 10 miles east of Mohnyin (24° 47′ : 96° 22½′); between latitudes 25° 28′ and 25° 52′ and longitudes 96° 7′ and 96° 24′ and at a locality 200 miles north of Myitkyina. Several other occurrences are recorded by the same author between North latitudes 25° 20′ and 26° 0′ and East longitudes 96° 5′ and 97° 0′ (*Rec. Geol. Surv. Ind. 62*, p. 108, *1929*; *63*, p. 99, 1930; *64*, p. 78, 1931). They are aligned along a N E.-S W. direction.

Peridotite masses, usually altered to serpentine and sometimes associated with steatite, occur 24 miles south-east of Fort Hertz (27° 21′: 97° 24′) as a lense-like outcrop over 5 miles long. About 100 miles south of this there are two groups of outcrops near Myitkyina (25° 23′ : 97° 24′). The eastern group extends from a locality about 4 miles north-east of Myitkyina for a distance of 60 miles to the south; while the western group which is 15 miles west of this, is 25 miles long, trending in a N. by E. direction.

In Manipur State, near the border of Assam and Burma, there is a large outcrop 25 miles east of Imphal, extending for 40 miles or more in a N. 15° E. direction between latitudes 24° 10′ and 25° 5′. It is several miles wide. Another outcrop is known east of Kohima in the Naga Hills, running for 15 miles in a SSW direction from a locality having the coordinates 25° 50′ N. : 95° E. Numerous small outcrops, some associated with chromite, are known in Thayetmyo, Minbu, Pakokku, Kyaukpyu, Prome, Henzada and Bassein districts of Burma, between 17° 20′ N. and 21° N. and 94° E. and 95° E. (Chhibber 1934*a*, pp. 245-246; 1934, pp. 314-317, 470-472). In the southern continuation of this zone, serpentines are found in all the three Andaman Islands and in Teressa, Tilanchong and Kamorta Islands of the Nicobar group (Tipper, 1911, pp. 10, 14; Gee 1926, p. 214). Rocks from the Andamans, which were formerly assumed to be tuffs, have recently been found by K. Jacob to be radiolarites (Jacob, *in the press*).

From investigations in various orogenic belts of the world, it has been learnt that during the course of development of a geosyncline, the *sial* layer is weighed down and stretched. Through cracks developed in this layer under tension, magma from the basaltic layer rises up and spreads into and over the sediments, forming intrusions and contemporaneous intercalations with them (Umbgrove, 1947, pp. 77-81). This accounts for the large masses of basic volcanics associated with geosynclinal sedimentation—*e.g.*, in the Dharwarians, Cuddapahs, Iron-ore series, Cretaceous of Baluchistan, etc.

The occurrence of ultrabasic rocks in the intensely deformed and sheared orogenic belts has now been established by Hess (1937*a*), in

particular in the West Indies (1938, pp. 332-333) and in the Island arcs of the Western North Pacific (1948). Thayer and Gould (1947) have also demonst ated the association of the shear belts of Cuba with serpentine intrusions.

As a result of the experimental study of the MgO-$SiO_2$ -$HO_2$ system Bowen and Tuttle(1949) have come to the conclusion that typical olivine rocks (or olivine—orthopyroxene rocks) are intruded more or lessin a solid condition at a temperature about 1,000°-1,200° C. If the mass encounters water on the way or is attacked by hydrothermal solutions after emplacement, the orthopyroxene is first attacked, giving rise to talc and secondary olivine at about 650° C. With further lowering of the temperature to below 500° C., the minerals will be transformed to serpentine. If olivine is in excess of the correct proportion for complete serpentinisation, brucite may be formed at around 400° C. The iron content of the olivine and pyroxene would give rise to magnetite, which is often seen associated with serpentine. The presence of carbon-dioxide in the hydrothermal fluids would produce magnesite and free silica at a temperature below 500° C. Thus, depending on the conditions obtaining in the crust during or after the intrusion of the ultrabasic rock, the appropriate mineral or minerals would be formed in the intruded mass.

Mountain building is initiated by tangential compression of the crust. The *sial* layer is sharply downbuckled into a syncline into which ultrabasic rocks are intruded. The tightening of the limbs results in the intense crumpling and squeezing out of the sedimentary material which is then overthrust to either side as exemplified in the Alps and the Himalayas. The sediments of the synclines on either side of the downbuckle would also be stripped and would come up against the overthrusting sediments in consequence of the crust moving inwards and downwards to form the downbuckle. Thus would the Jura type of structures be formed. The different stages are illustrated by Hess (1937*a*, fig. 5) and are shown in Fig. 18.

Experiments performed by Kuenen (1936) with suitable materials show that, as compression is applied to a set of horizontally disposed layers, a series of gentle folds is first formed. With further compression, the main syncline buckles down, later forming a tight fold. Sometimes two adjacent synclines buckle down, forming a double structure. When materials representing light sediments are present over the synclinal stucture they are squeezed out and thrust over the sides. These experiments give considerable support to the ideas put forward by Vening meinesz (1934).

During the first great push downward, the synclinal fold reaches down to a depth of some 60 Km into the peridotite layer some material from which ascends into the axis of the fold either in the centre or on either side of the centre (Hess, 1937*a*, p. 271). This is what has happened in the Himalayas where we get two (including the Darchen zone) zones of ultramafic rocks which are here associated with the exotic blocks. The belt containing these ultramafic rocks is the main negative anomaly strip of the Himalayas. On either side of the downbuckle or

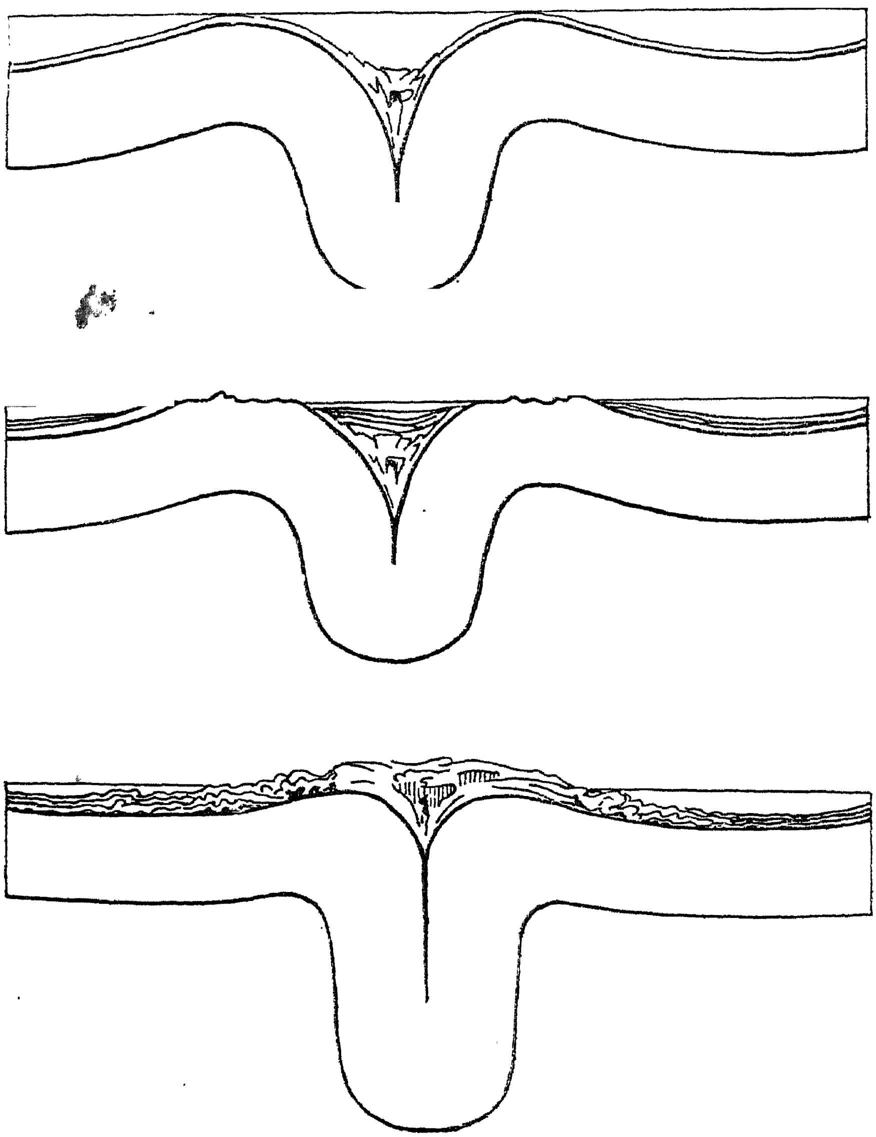


Fig. 18. (After H H. Hess)

tectogene (Hess, 1937, p. 75) there are usually somewhat wider strips of positive anomalies. Further deformation does not produce repeated intrusions of ultramafics as, by that time, the lower part of the tectogene would have softened and sealed off the peridotite magma from below. The later granitic intrusions in the tectogene are due largely to isostatic adjustments which bring up the highly heated lower part of the downfold as intrusions of molten granite and grano-diorite. The period of maximum uplift is therefore later than the period of intense compression, though deformation and thrusting must occur all through.

In the Himalayas the period of down-folding of the crust may be dated as the Upper Cretaceous since the ultramafics (enstatite-peridotites, etc.) of the exotic block regions are intrusive into the Upper *flysch* sediments of that age (Heim and Gansser, 1939, pp. 162, 185). The Tibetan facies of the Upper Cretaceous associated with these intrusions are grey and dark radiolarites which indicate deposition in a deep sea (Heim and Gansser, 1939, pp. 162-164, 173) whose deepening went on while the downfolding was in progress. Little is known about the geology of the country beyond the central Himalayan zone except the observations of Heim and Gansser, but the wide zone containing the two belts of ultramafics and exotic blocks may perhaps be due to the presence of two contiguous downbuckles suggested in Kuenen's experiments. It seems also likely that the zone of granite intrusions of the Trans-Himalayan range north of Mount Kailas may be due to the same cause, *i.e.*, the presence of a second downfold.

As compression increases in the geosyncline, uplift of the sediments will ensue. The lower portion of the down folded *sial* would begin to melt at depth and would be squeezed out to form intrusive masses of granite and granodiorite along the axis of the newly formed mountain. It may sometimes be accompanied by basic rocks, especially in the earlier stages, while the later stages will be marked by assimilation of sediments and migmatisation.

The ultrabasic intrusives in the Archaean mountain belts—Aravalli, Dharwar, Satpura—may be said to be generally of the same age as the period of folding and deformation, though the results of careful and detailed studies are wanting. In the Tertiary mountain belt, the ultrabasics so far known in Baluchistan, in Ladakh and Kumaon, and at various localities in the Burmese arc are assigned an Upper Cretaceous age, which fits in with our deduction of the age of the first diastrophism in the region.

## SEISMIC PHENOMENA

Seismic phenomena in India, their distribution and significance in relation to structure have been dealt with in a general way by T. Oldham (1883), Count Montessus de Ballore (1904) and West (1937), while individual earthquakes of importance during the last 50 years or so have been described by various geologists and meteorologists.

The Peninsular part of India is immune to all but very minor shocks which are occasionally recorded. These may be due to local disturbances produced along the fractured western coast of India or to the sedimentary loads deposited in the sea by the larger rivers. The sympathetic shock reported at Cochin at the time of the Bihar earthquake of January 15th, 1934, is apparently of such a nature.

Earthquakes of considerable intensity occur all along the fold belt of the Baluchistan, Himalayan and Burmese arcs. Occasionally also they have occurred in the floor of the Gangetic depression and in and around the fractured horst of the Assam plateau. The Bihar earthquake of 1934 is attributed to movement in the fractured and alluvium-filled floor of the fore-deep (Dunn *et. al.* 1939), while the Dhubri earthquake of 1931 was caused by adjustment along the faulted north-western margin of the Assam plateau (Gee, 1934). The Cutch earthquake of 1819 (R. D. Oldham, 1926) may be attributed to a fault at the junction of the folded sedimentaries of Cutch and the Archaean rocks lying to their north, or to a zone parallel to it within the folded rocks themselves.

In the Assam-Burma region, seismic phenomena may be manifested along one of the overthrusts of the Burmese arc ; along the fault zone which separates the above mountain belt from the Tertiaries to its east ; or along the fault zone which separates the Tertiaries from the ancient sedimentaries of the Shan Plateau.

Plate 2, showing the epicentres of earthquakes recorded by seismological observatories in recent years, has been prepared from data contained in the recent work of Gutenberg and Richter (1949), supplemented by those from papers by Pendse (1948) and Sohoni (1950) of the India Meteorological Department. Epicentres of shocks originating at shallow depths (normal) are shown by dots while those originating at greater depths are marked by crosses on this map. The epicentres show a wide distribution in the Tertiary orogenic belt of Burma, the Himalayas, Baluchistan and Iran. There is a clear indication of a seismic belt in the Carlsberg Ridge system in the Arabian Sea. A very conspicuous clustering of epicentres of shocks of both shallow and intermediate focal depth occurs in the Pamir—Hindukush region where,

apparently, active readjustments are still taking place as a result of the late Tertiary Himalayan movements. Clustering on a limited scale is also indicated in the region of Quetta in Baluchistan. These may perhaps be attributed to the disturbances caused by the wedge-like projections of the Indian shield which are directed towards these regions and have produced high compression in the crust as evidenced by the remarkable bends of the outcrops of strata and of the orographic features.

We have already seen that the Himalayas are typical folded mountains which resulted from the compression of a geosynclinal trough. The core of the mountain belt exhibits large masses of granitic intrusives as well as some basic and ultrabasic rocks. On the convex side of the mountains, *i.e.,* on the side of India, there is a trough filled with Pleistocene and Recent alluvium.

Gravity observations in India show that there are several zones and areas of positive or negative anomalies, after corrections have been made for topography and isostasy (Plate 3). It is now generally accepted that irregularities of surface topography are more or less compensated for by excess or deficiency of matter, as the case may be, in the lower crustal layers and that at some depth, of the order of 60 miles, complete compensation or equilibrium is attained. In spite of nature's effort at isostatic compensation, there are many regions where notable anomalies exist, particularly in folded mountains, in 'island arcs' and in ocean deeps near them, whatever hypothesis of compensation is advocated and applied. Such regions of marked anomalies always indicate geological instability, foreshadowing further changes.

From an examination of the plumb-line deflections in India, Sidney Burrard of the Survey of India came to the conclusion that the effect of the Himalayas was modified by the presence of heavy or light masses of sub-crustal rocks in certain regions. He thus deduced the presence of a sub-surface ridge of heavy rocks running across India roughly east to west through the region of Jubbulpore, and a parallel zone of light rocks passing through Belgaum and Nellore in South India. The former is often referred to by the Survey of India as 'Burrard's Hidden Range' on the supposition that the heavier layers of the earth's crust (*Sima* and peridotite layers) have here come nearer the surface and formed a sort of anticlinal ridge. The corresponding zone of lighter rocks in South India (Nellore-Belgaum) is referred to as 'Burrard's Hidden Trough', expressing the idea that the lower layers of the crust have been depressed into a synclinal trough which is occupied therefore by a larger thickness of the light rocks of the upper crust. North of the 'Hidden Range' is another parallel zone, passing through the valley of the Indus and Brahmaputra rivers and Manasarowar Lake, beyond the main Himalayan range, which is also a 'trough', (Glennie, 1932, Chart I).

According to Glennie (1932, p. 3), the sedimentary trough of the Himalayas is deepest along the Indus-Brahmaputra valleys north of the main Himalayan range. This trough line follows the general curvature of the Himalayas while the 'Hidden Range' and the 'Hidden

# GEODETIC EVIDENCE

down of the upper crust in front of the convex mountain arc. The Brahmaputra Valley in Assam is a continuation of the same feature. It was first thought that the Gangetic Valley was a V-shaped depression filled with alluvium having a thickness of perhaps up to 50,000 ft. (Burrard, 1912). Such a thickness has since been shown to be improbable by Jeffreys (1929, p. 201). Some geophysical measurements made in Bihar after the 1934 earthquake show that the alluvium is about 6,000 ft. thick there. It is not known whether this is an average thickness or the maximum. In any case, an upper limit of perhaps 10,000 ft. for the thickness of the alluvium is now thought reasonable.

To the north of the Himalayan region is a belt of negative anomalies passing through the Pamirs and Ferghana Valley where the free-air anomalies are said to attain magnitudes of about minus 150 milligals. From the isostatic anomalies for this region, worked out by using different hypotheses, it has been deduced that the crust here (*i.e.*, the *sial*) may be as much as 22 to 35 km. thick (Gulatee, 1940, p. 55). Mushketov (1936) has suggested that this region is one of recent uplift in addition to having been affected by the Himalayan orogeny.

Vening-Meinesz explains the formation of mountain chains as due to a downward buckling of the *sial* deep into the *sima*. During the process, the down-buckle reaches into the peridotite layer, the material from which rises up into the axial part of the fold. Later basic and acid magmas are injected profusely into the same region and large intrusives of granite result from the remelting of the *sial* crust which has been depressed. It is the deep down-buckling of the *sial* which gives rise to negat ve anomalies along the zones of mountain building. The down-buckle causes the displaced basic magma of the basaltic layer to rise on either side of it, producing somewhat broader zones of positive anomalies ; but the positive anomalies are, as a rule, smaller in magnitude than the negative anomalies of the down-buckled zone.

In a subsequent paper, Glennie (1940) has explained the various regional anomalies as due to local upwarps or down-warps of the subcrustal heavy layers. In some cases they have no direct connection with the surface geology. For example, though the Deccan Traps occupy a large area, the anomalies are by no means unifo m over that area and are indeed erratic. A belt of high positive anomalies runs through the Gulf of Cambay and along the Bombay coast, which may be attributed to basalt having come up comparatively close to the surface. A similar upwarp of the basaltic layer may also be present along the western end of the Satpuras by the side of the Narbada river.

There are, however, a few interesting coincidences between the crusta warp map and the surface geology. For instance, the highly compressed, granite-injected Archaean ranges of the Aravallis, Dharwars

and Satpuras, the Assam Plateau and Shan Plateau are regions of positive anomaly, while the Cuddapah basin of Madras, Chattisgarh and Gwalior which contain thick unmetamorphosed sediments are zones of negative anomaly.

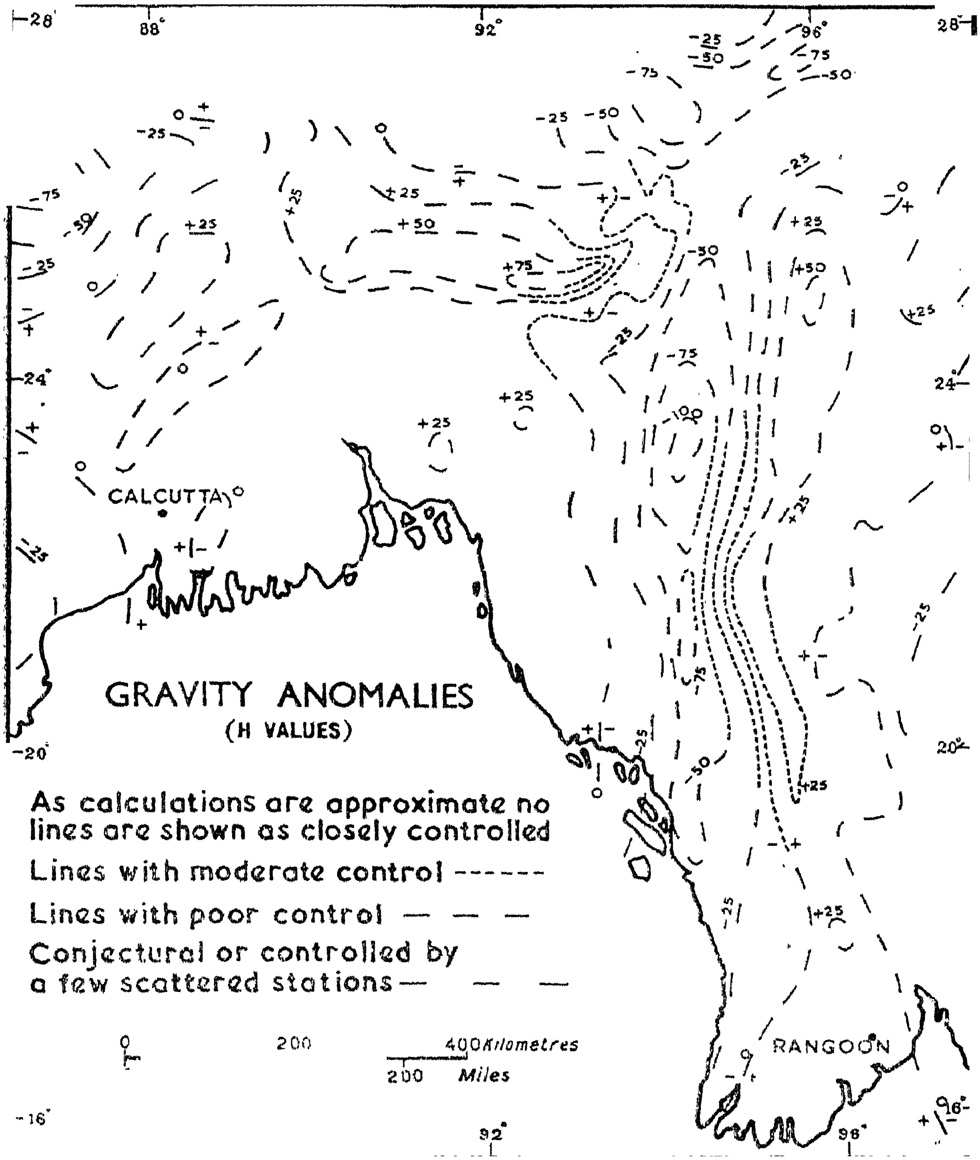



Fig. 20.—Gravity Anomalies (H. Values) in Assam and Burma.
(After P. Evans and W. Crompton)
(*By Courtesy of the Geological Society of London*)

In a recent paper, Evans and Crompton (1946) have given the results of the gravity survey of the Assam-Burma region in which gravity

observations were recorded at about 6,000 stations. In addition to the conventional isostastic anomalies, they have also computed the anomalies after carrying out corrections for local geology. The geological corrections have been carried down to a depth of 11·5 kms., as data about the formations and their specific gravities were available from extensive records of bore-holes put down for petroleum by the Burmah Oil Company (Figs. 19 and 20 which are reproduced here with the kind permission of the Geological Society of London).

There is a marked zone of negative anomaly along the eastern flank of the Burmese (Assam-Arakan) arc continuing apparently into Andaman-Nicobar Islands. This is the zone of maximum uplift during the Tertiary mountain building movements, containing great thickness of Tertiary sediments.

There is a zone of high positive anomalies along the volcano belt of Burma, containing the volcanos Taungthonion, Wun-tho, Monywa, Popa, Barren Island, etc., continuing into the volcano zone of Sumatra and Java. The Shan Plateau shows only weak positive anomalies as it is a long time since it experienced mountain building activity.

The Assam plateau is a region of high positive anomalies. There is little doubt that it is continuous with the Bihar Archaeans. The Upper Assam Valley as well as the Ganges Valley in Bihar are regions of negative anomaly as they are troughs filled with thick recent sediments.

It is a matter of interest that the Red Sea is an area of positive anomalies in contrast with the East African Rift Valleys which show negative values. Though the Red Sea is generally considered to be part of the Rift System, the rift here is of large dimensions and partakes of the character of the much larger rifts of the Atlantic and Indian Oceans. The Red Sea bottom, it would appear, is largely denuded of its *sial* crust and the basaltic sub-stratum must be fairly close to the sea bottom. Bullard (1936), who investigated the gravity conditions of the East African Rift areas, is of the opinion that these rifts were not tension fractures but were really formed by compression and faulting.

Vening-Meinesz found that the anomalies over large parts of the Atlantic Ocean are positive, of the order of +36 milligals (Hayford values). Since both the Atlantic and Indian Oceans are thought to have been formed by rifting and by the drift of the sides apart, they should show closely similar characters, including gravity anomalies. The Mid-Atlantic and Mid-Indian Ocean ridges should also show similarity to each other as they have evidently been formed as a result of the same cause and in an identical manner.

# SUMMARY AND CONCLUSIONS

We have seen that India, excluding the mountain belts surrounding it in the north, is an ancient stable mass or 'shield' which has suffered little folding since the Pre-Cambrian. The ancient grain is along four major regional trends :—

(i) The Aravalli trend in Rajputana (NE.- SW.) spreads out in Gujarat, one branch going into the Laccadives through the Gulf of Cambay and the other into Mysore and Hyderabad.

(ii) The Dharwarian trend (NNW-SSE) of Mysore and Hyderabad is most probably the southerly continuation of the Aravalli trend. The trend in the southernmost districts Madura and Tinnevelly), in north-eastern Hyderabad and in the hinterland north-west of the Eastern Ghats in Orissa and parts of the Central Provinces, which is NW-SE in general, may be the extension of the same Dharwarian influence.

(iii) The Eastern Ghats trend is characteristically NE-SW all along the Eastern Ghats from north-east Orissa to the Kistna river. The northern part occupies a broad area, in the western half of which the trend is NNW-SSE as seen typically in the Iron-ore Series and iron-ore ranges of Keonjhar-Bonai-Singhbhum. In the Nellore region bordering the Cuddapah Basin, it shows a sigmoidal curvature with a slight convexity to the east and finally veers to the SW near Madras and to the ENE-WSW in Coimbatore and the Nilgiris. It is thought that the same trend becomes E-W in South Malabar.

It will be noticed that this belt cuts across, and is superposed on, the Dharwarian trend, separating the Mysore from the Madura-Tinnevelly areas.

(iv) The Satpura trend (ENE-WSW) characterises the rocks of Narbada-Son drainage region continuing into northern Bihar and the western part of the Assam plateau. A southerly branch is seen in Nagpur -Chindwara-Balaghat region of the Central Provinces, and Gangpur and Singhbhum further east. The area between the two is occupied by granites and gneisses with the same general trend. At its western end it appears to merge into the Aravalli trend where the latter splays out widely. In Bhandara in the Central Provinces, and in Southern Gangpur in Orissa, there are two small areas where a triangular pattern due to the coming together of these trends is seen.

Regarding the relative ages of the orogenies which have produced the above regional strikes, it would appear that the Aravalli and Dharwar are identical. The Eastern Ghats trend which is superposed on (and flows around) the Dharwarian seems to be younger. There are indications in Gangpur (Orissa) that the Satpura trend is younger than the one whose vestiges are found there, presumably the Eastern Ghats trend. Holmes has come to the same conclusion from structural considerations as well as from data on the age of radioactive minerals found in pegmatites traversing these belts. But, as Fermor has pointed out, this does not settle the ages of the Archaean and Pre-Cambrian formations of the different regions.

On the Archaean basement were laid down thick deposits of Algonkian age (Cuddapah and Vindhyan), remnants of which are found in the Cuddapah basin of Madras, the Chattisgarh-Mahanadi area of the Central Provinces and Orissa, and the great Vindhyan basin of upper India. The Cuddapahs are more disturbed than the Vindhyans which have generally suffered little or no folding or metamorphism. The eastern margins of the Cuddapah and Chattisgarh basins and the southern margin of the great Vindhyan basin have suffered some folding and disburbance from forces which followed the older trends of the particular areas. The western margin of the great Vindhyan basin is marked by a fault of great magnitude along which the Aravallis and Delhis have been uplifted and thrust against the Vindhyans, probably in the Mesozoic.

The Gondwanas were ushered in by a great ice-age. Over the initial tillites were laid down fluviatile and lacustrine strata containing the *Glossopteris* flora and coal seams in the Permo-Carboniferous and Permian. This was followed by semi-arid conditions characterised by red sandstones and sandy clays with amphibian and reptilian remains. Again followed a more moist era in the Upper Gondwana (Jurassic), characterised also largely by fluviatile and lacustrine sediments in which the flora is of the *Thinnfeldia-Ptilophyllum* group. Marine incursions appeared on the eastern coast showing that this coast was already taking shape in the Jurassic. The Rajmahal area appears to have undergone some slight folding in Upper Triassic times, followed by eruptions of basic lava in the Middle Jurassic. The marine deposits on the eastern coast are apparently Upper Jurassic to Neocomian. Then occurred an uplift and erosion, as a post-Jurassic peneplane is recognised.

To the north and northeast of India, there was a sea from the Cambrian onwards. The Cambrian sea stretched into Indo-China and Southwest China and into Australia. During the Ordovician and Silurian, this sea connected with the American area probably through Southern Europe, while the Burma-China sea connected with the Baltic. In the Middle Devonian, the barrier separating the above mentioned two seas seems to have been removed, at least partially. In parts of the Hima-

layan area there seems to have been marine regression and shallowing of the basin in the Devonian.

The Middle to Upper Carboniferous Hercynian revolution, which brought into existence several mountain ranges in Central and Northern Asia, also saw the establishment of a great latitudinal geosyncline (the Tethys) stretching from the Alps through Iran, Baluchistan. Himalaya, Burmese and Banda arcs to New Guinea and also into Western Australia. At the same time, Gondwana sedimentation was initiated in the Southern Continent (Gondwanaland). An arm of the sea, probably very narrow, seems to have extended in Permian times to Rewa in Central India from Southern Rajputana through Cutch and the Narbada Valley, but the Tasman geosyncline of East Australia was cut off from the Tethys in Lower Permian. Sedimentation continued in the Tethyan basin right through the Mesozoic, till it was broken up by the Himalayan orogeny in the Upper Cretaceous and Tertiary.

A rift, which later developed into the Indian Ocean, was formed between Africa and India-Madagascar in the Permian. This was gradually widened subsequently. This rift extended southward into Patagonia in the Cretaceous. India began to drift from Madagascar and Africa perhaps also in the Cretaceous.

The Red Sea rift appears to have developed in the Upper Triassic and Arabia also drifted north-east, with probably an anti-clockwise twist in the Cretaceous.

The Callovian unconformity (regressions) in the Himalayan area is more or less coincident with the marine transgression over Southern Rajputana and Cutch. To the south of Cutch and Kathiawar there must have been land, *i.e.*, a westward extension of the Peninsula which seems to have been faulted down in the Miocene.

The Middle Cretaceous was a period of intense orogeny in Oman. As a result, the sediments of the Oman basin were pushed back to the north-east and uplifted into mountain ranges, accompanied by eruptions of lavas and intrusive granites and serpentines. It would appear that, because of the northerly drift of India at the same time, a milder orogeny took place in the Baluchistan arc accompanied by volcanics and intrusive serpentine, assigned to the Upper Cretaceous. There is evidence of a shallowing of the margins of, and of the intrusion of ultrabasic rocks into, the Himalayan area of the Tethys at about this time. The Jurassics of Cutch were folded and the folding movements apparently affected the Gondwana sediments of the Narbada-Son Valleys. The Great Boundary Fault of Rajputana, along which the Aravalli belt was thrust up against the Vindhyans on its east, may also have been formed at this time (or earlier), as it is a compression

phenomenon, and is pre-Deccan trap in age. That is to say, the compressive effects on the Baluchistan arc may have been felt in the Aravalli belt which was overthrust in a south-easterly direction on the Upper Vindhyans. The Burmese arc, continuing through the Nias-Mentawai ridge into the Banda arc was folded in Laramide times, a little later than the period of folding of the Oman and Baluchistan areas. In this long belt, the Laramide orogeny initiated by the northward drift of India would appear to have been helped by a similar drift on the part of Australia and New Guinea at the other end. At the same time, the stable mass of Cathaysia and Indo-China were probably gradually spreading out to the east and south, contributing thereby to the formation of island arcs.

Then followed a period of tension during which the Deccan Traps were erupted at the end of the Cretaceous and in Lower Eocene. Vast amounts of lava have risen through the weak zones of Cutch, Kathiawar, the Narbada Valley and alongside the Aravalli axis parallel to the Bombay coast as well as through numerous fissures elsewhere. The later dyke swarms are largely confined to the above mentioned zones in western India and may have been intruded late in the Eocene. Faulting occurred later, as a result of which segments of the crust in these areas have foundered differentially.

The Gondwana trough faults may have been formed any time after the Jurassic, as precise data on the age of the trough-faults are lacking.

The great Cenomanian transgression invaded parts of South India, Assam-Burma, West Australia, Madagascar and East Africa. From this time onward, these areas show an Indo-Pacific fauna while Arabia, Baluchistan and the Narbada Valley were invaded by a gradually increasing Mediterranean element which came through Syria and mingled to some extent with the Indo-Pacific fauna.

The Himalayas were formed during a series of great orogenic movements separated by periods of comparative quiescence. The initiation of deformation seems to have taken place in Upper Cretaceous. Heim and Gansser (1939, 162-163, 173) state that the ophiolitic rocks are intrusive into the Upper Flysch of Upper Cretaceous age and are associated with grey and dark radiolarites of deep sea deposition belonging to the Tibetan zone. The deep sea deposits must represent the period when the downbuckling was taking place. The exact dating of the ultramafic intrusions must await further work in the Central Himalayas. The later movements took place in uppermost Eocene, in Middle Miocene, at the end of Pliocene, in Pleistocene and even in Sub-Recent times. The Mid-Miocene orogeny is considered to be the most violent of all when great masses of granite were intruded into the axial region of the main Himalayas. The succession of mighty ranges

one behind the other, the great magnitude of the thrust-sheets (nappes) and the violent disarray of the rocks, all point to a tremendous shortening of the crust in a direction at right angles to the Himalayan arc, amounting to many hundreds of miles. In the Banda arc there were movements in (?) Oligocene, Mid-Miocene (e4), Upper Miocene (f2) and early Pleistocene, the Upper Miocene one being the most intense. From the data on palaeogeography and diastrophism contained in Umbgrove's recent publication (1949) it is clear that it is the outer arc of the East Indies (the belt of negative anomalies) that corresponds to the axis of the Burma-Andaman arc.

Within India, the Assam wedge lying in the angle formed between the Himalayan arc on the north and the Burma arc on the east and south-east, was overthrust from both the sides. Faults developed around the Assam Plateau and it was uplifted in or about the Middle Miocene.

There was a marine transgression of Middle Miocene age along the coasts and this separated Ceylon from the mainland by a very shallow sea. At the same time a strip of unknown extent which certainly included the southern part of the Aravalli belt, was faulted down along the West Coast, giving the final outline to that coast. The Mekran Coast was faulted down in the Pliocene, for we find Upper Miocene sediments are involved in it. The Oman and South Arabian coasts were faulted in post-Eocene times, perhaps in the Oligocene or Miocene.

The intense mountain building movements produced a depression or 'fore-deep' in front of the convex side of the Himalayan arc because of the bending down of the northern edge of India which came into opposition with the Central Asian mass. This fore-deep is not a continuous depression throughout the length of the Himalayas, but consists of three strips on the same alignment, separated from each other by transverse ridge-like structures west of Delhi and in the region east of Cooch-Behar. The troughs correspond more or less to a strip of negative gravity anomalies. There is another negative strip along the Indus-Brahmaputra Valleys in Tibet north of the main Himalayan range.

The last-mentioned negative strip is parallel to Burrard's 'Hidden Range' and to the 'Hidden Trough'. They are separated from each other by a distance of about 8° to 8½° of latitude. As the latter two features cut across a variety of geological formations, they are attributable to the depression or elevation of the sub-crustal layers. The parallelism of these to the Himalayan arc, and the correspondence of the northern negative strip with the deep part of the Tethyan basin, indicate that they all resulted from a single cause, *viz.*, the Himalayan orogeny and the northward drift of India. The Hidden Range and Trough

suggest the crest and trough of a sub-crustal wave generated during the drift which has not yet had time to be smoothed out.

The fore-deep, or at least the northern part of it, is doubtless underlain by Tertiary and older rocks which dip down into it from the Himalayas. Similarly, the rocks on the Peninsular side may also be expected to continue into it from the south. The bottom of the trough is likely to contain fractures which may have been formed when it was bent down. Such a fracture zone, being a zone of weakness, is thought to be adequate to provide a locus for earthquake shocks. Indeed, the Bihar earthquake of 1934 has been attributed to movement in such a zone underlying the Ganges Valley.

The two extremities of the Himalayas are marked by wedges of the Peninsula jutting out to the north-west and north-east respectively. The influence of these wedges is felt as far north as the Pamir region in the north-west and S. W. China in the north-east, for the mountain ranges there show conspicuous sharp bends towards the appropriate direction in these places.

If we examine a geological map of the Tethyan geosynclinal belt from Iraq through Iran, Baluchistan, Himalaya and Burma to the Indonesian archipelago, we see that the general direction of the Iraq-Persian Gulf region points directly towards Sumatra and is continued by the Indonesian arc. But it is violently distorted and pushed to the north by the foreign mass of India just as Southern Iran is distorted by the Arabian mass. It seems, therefore, not unreasonable to assume that the line connecting Iraq and Indonesian arcs was not far from the original position of the southern limit of the Tethyan geosyncline and that the distortion of the line gives us roughly a measure of the drift of India to the north (or N. N. E.) and of the shortening of the crust by the compression involved in Himalayan orogeny. The distance between the postulated original position of the southern limit of the Tethyan geosyncline and the southern limit of the Himalayan arc is about 13 to 14 degrees of latitude or some 800 miles.

Heim and Gansser (1939, p. 226) have made an estimate of the original width of the sedimentary zones of the Himalayas and deduced the shortening of the zones as a result of mountain building.

The zones are :—

1. The old Gondwana continent buried under the Gangetic alluvium.
2. The autochthonous region of the Simla Slates and the Eocene Subathus, partly covered by the Siwaliks; original width perhaps 100 km.

3. The exterior sedimentary zone of the Lesser Himalaya with the Mandhali-Nagthat-Blaini-Krol-Tal succession; original width perhaps 20 km. or more.
4. The interior sedimentary zone of the Lesser Himalaya with unfossiliferous limestones, dolomites, shales and quartzites of the Tejam-Pipalkoti zone (possibly the equivalents of Krol-Tal); this underlies the crystalline sheet and is thrust over the autochthonous zone; original width perhaps 100 km. or more.
5. The missing normal sedimentary cover of the crystallines of the Lesser Himalaya which must have contained the passage from the unfossiliferous rocks of the Gondwana border to the fossiliferous Tethyan facies; this must have had a width of at least 120-150 km.
6. The Himalayan Tethyan zone 110-130 km. wide; northern Himalayan ranges 20 km. wide.
7. The zone of Chilamkurkur considered as the normal northern extension of zone No. 6.
8. The supposed passage zone to the Tibetan facies (Exotic blocks etc.) which is now entirely unknown.
9. The Tibetan facies (Kiogad and Exotic facies) representing a deep-sea facies—width unknown.
10. Zone of the Trans-Himalaya—width unknown.

The estimated width from the northern border of the Indian plains to the Exotic zone is thus, according to these authors, 100+20+100+120+100+20=460 km. as a minimum. The actual width of these zones at present is about 160 to 170 km., so that the difference between the two, about 300 km., would represent the shortening of the crust. However, it should be pointed out that this estimate may be out by 100 to 200 per cent.

In making an estimate of the shortening of the crust in the Indo-Tibetan region, it should be realised that the Tertiary orogeny affected the whole region from the northern border of the Indian Peninsula to the Kun Lun ranges in Tibet and formed a whole series of mountain ranges—the Himalaya, Ladakh-Kailas, Trans-Himalaya, Karakorum and Kun Lun. According to Mushketov (*see* Gregory, 1929, p. 178) the Alpine-Himalayan mountain building movements affected all the region up to the Trans-Alai where the early Tertiary thrusts are directed towards the north. The same author states (1936, pp. 885-894) that the Alpine thrusts in the Kun Lun—Karakorum region are superposed on the older (Variscan) folds. 'Vast portions of the Palaeozoic

structures (Kunlun, Alai, Tienshan) were welded to the Tethyan folds, with which they form a large unit ', according to De Terra (1936, p. 869). Marine conditions in the Karakorum and Kun Lun regions gave place to estuarine and land conditions after the late Cretaceous upheaval of the Tethyan basin; in fact, De Terra calls the first Himalayan orogenic upheaval as the *Karakorum phase* (De Terra, 1936, p. 859). The vastness of the region affected and the succession of the mountain ranges formed by the Himalayan revolution would support the deduction indicated above (about 800 miles) about the magnitude of the crustal shortening.

In an indirect way, we may gauge the magnitude of the compression from a look at the geological map of Baluchistan. The Mesozoic and Tertiary succession (itself subjected to broad folding) seen between latitude 30° N. and the submarine continuation of the Kirthar range off the Mekran coast at about latitude 23° N, is gathered up and tightly compressed into less than one-fourth of its width in the Sibi-Quetta region by a projecting wedge of the Peninsula. The compression of the Tethyan basin between the masses of India and Central Asia should be at least of the same order.

The intensity of the compression of the Tethyan geosyncline has found expression in the great recumbent folds and thrust sheets seen in the Himalayan region. The lateral arcs (the Baluchistan and Burmese arcs) were formed at the same time by the sediments at the sides being comparatively mildly thrust over the north-eastern and north-western borders of India. Though the folding in the lateral arcs is often of considerable intensity it is not so violent as in the Himalayan region where the sediments have been piled up to form the highest mountain ranges in the world. The violence of the movements has been responsible for the almost complete absence of unbroken structures suitable for accumulation of petroleum in the Himalayan region. The Baluchistan region has suffered more than the Burmese, because of the presence of two wedges (near Quetta and Dera Ismail Khan) of the Peninsula distorting the smoothness of the arc.

The thrust phenomena around the tips of the Kashmir and Assam wedges are interesting. In the former, the formations almost turn a full circle over to the west and south-west, the thrusts being directed everywhere at right angles to the strike of the rocks. The rocks have literally ' flowed ' around the tips of the wedges and the direction of flow is anti-clockwise in the Kashmir wedge and clockwise in the Assam wedge, as pointed out by Du Toit (1937, p. 184).

Our knowledge of the geology and the details of the structure of the Himalayas and associated mountain ranges is still very meagre. The area is large and inaccessible and it will be many years before even

parts of the gaps in our knowledge are filled up. Wadia has remarked 1938, p. 117) :—

> "The plan of the great edifice of the Himalayas is discernible only in the haziest outline yet. We cannot be so bold as to say that the Himalayas are built on the plan of the Alps, nor even that their architecture is individual. No doubt several tectonic features are common and the Alpine-Himalayan axis of earth-folding originated in one common and continuous impulse. But the proportions are so vastly different............the one may be like an ornately built, delicately chiselled chapel, and the other a huge sun-altar of rough-hewn blocks".

## ACKNOWLEDGMENTS

The writer is indebted to his colleagues Dr. K. Jacob, Mr. M. B. Ramachandra Rao and Mr. N. A. Vemban for providing him with certain data and discussing with him certain aspects of the subject. His thanks are due to Prof. Mahadevan (Andhra University), Dr. J. B. Auden (Geological Survey of India) and Dr. D. N. Wadia (Geological Adviser to the Department of Scientific Research, Government of India) for reading through the manuscript and making several valuable suggestions.

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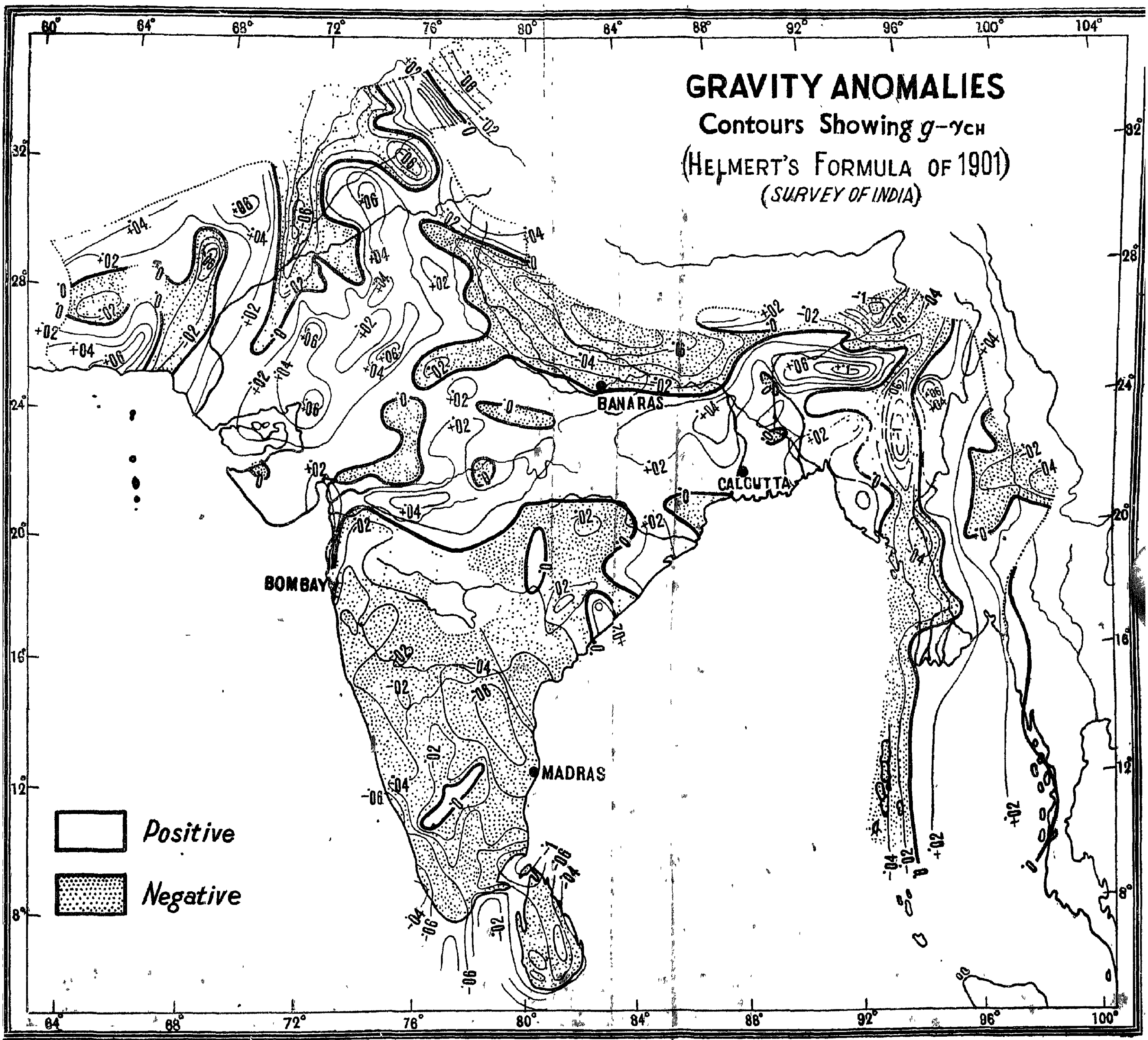
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# BULLETIN No. 20

OF

# National Geographical Society of India,

BANARAS

IN THIS ISSUE

PRESIDENTIAL ADDRESS

DELIVERED TO THE

**Geology and Geography Section of the 41st Session of the Indian Science Congress, Hyderabad-Deccan, 1954.**

**Part I: The Drainage Patterns observed in India and the adjacent Countries.**

**Part II: The Development of Landforms in the Himalayas.**

*Issued January, 1954.*

Published by the
National Geographical Society of India, Banaras.

*Price Inland*: Rupees Three. *Foreign*: Five Shillings.

# SECTION OF GEOGRAPHY AND GEOLOGY

PRESIDENT

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University Professor and Head of the Department of Geography, Banaras Hindu University.

## Presidential Address*

*(Delivered on January 5, 1954)*

**Part I : The Drainage Patterns observed in India and the adjacent countries.**

**Part II : The Development of Landforms in the Himalayas.**

I thank you most sincerely for the honour you have done me in electing me the President of your Section this year. I must refer to a very outstanding event of the year. I mean the conquest of Mount Everest by Tensing Norkay and Edmund Hillary. This achievement is the crowning success of a series of British and other expeditions and augurs well for the co-operative effort of different nations in the cause of mountaineering and exploration.

I may also refer to the sad demise of Shri P. K. Dutt, Lecturer in my Department on the 28th July, 1953. He has been snatched away at a very young age of about 30. Indian Geography has suffered a great loss by his premature expiry.

I have divided my address in two parts : I. The Drainage patterns observed in India and the adjacent countries. II. The Development of Landforms in the Himalayas. You are aware that in both these subjects I have been actively interested at least for the last decade. Among other regions in the Himalayas

*An illustrated account of the Presidential Address delivered on the 5th January, 1954 to the Geology and Geography Section of the Indian Science Congress, Hyderabad-Deccan.

I have especially investigated the following and they are mentioned below in order of their investigation :—

(1) The Tehri-Gangotri Region in the Tehri Garhwal Himalayas.
(2) The Doon Valley and the adjoining Siwalik Range.
(3) The Katmandu Valley and the adjoining Nepal Himalayas.
(4) The Kashmir valley and the adjoining Himalayas. I may add that my acquaintance with this part of the Jammu and Kashmir Himalayas dates back to 1922, when I first visited it as an M.Sc. student. Within recent years I have spent my several summer vacations in the careful investigation of this interesting region.
(5) The Simla Region.

All this work has been indeed strenuous, more especially when completed with very meagre resources. In the Tehri Garhwal Himalayas my kit and that of the two servants were carried by a single mule, while in Nepal it was transported by three coolies. I lived on a vegetarian diet available in the country.

I shall now first discuss the development of various drainage patterns in India and the adjacent countries.

The drainage patterns in general are to be classified into :— *(a)* Consequent, i.e., those which are related to the underlying structure and uplift of the country, *(b)* Insequent which bear no relation to the underlying structure of the region.

## I. CONSEQUENT DRAINAGE PATTERNS

(i) *The Great Himalayan Rivers* :—This group comprises the Ganga and its following tributaries, the Yamuna, the Sarda, the Gogra, the Gandak and the Kosi. They rise from the southern slopes of the Great Himalayas. The main features of these rivers have already been discussed.[1]

From an investigation of the river terraces of these rivers the author has arrived at the interesting conclusion that they

assumed their present form either towards the close of the Tertiary Era or about the beginning of the Pleistocene Period when the Himalayas had attained their present elevation.[2]

(ii) *The Lesser Himalayan Rivers* :—Commencing from the east we have the Bagmati which rises in the range just north of the Katmandu Valley. Likewise the Rapti, the Ramganga and the Khoh together with some of the tributaries of the Indus, viz., the Beas, the Ravi, the Chenab and the Jhelum belong to this category.

(iii) *The Siwalik Rivers* :—The Hindan and the Solani could be cited as instances of the rivers, which take their rise in the Siwalik Range.

(iv) *The Rivers of the Gangetic Plains* :—The Gumti, which has its source in the Pilibhit District and the Barna or the Varuna which meets the Ganga near Banaras provide good examples of this class of rivers.

## Anterior Drainage

In a separate communication the author has analysed the development of the drainage of the Ganga which presents several peculiar features of its own. An interesting characteristic is that the tributaries flowing from the south into the Yamuna or the Ganga, viz., the Chambal, the Sindh, the Betwa, and the Son are much older than the Ganga and the Yamuna comprising the main rivers of today. Likewise the Rihand and the Kanhar are older than the Son. The main tributaries flowing from the north, viz., the Gogra, the Gandak and the Kosi are, however, of the same age as the Ganga. No doubt, these tributaries from the south were discharging their waters into the Tethys geosyncline when the main rivers, viz., the Ganga and the Yamuna and their tributaries from the north, had not come into existence yet. The older tributaries from the south form a type of their own and such rivers the author has styled as the *anterior* tributaries or *anterior drainage*.

## B. Radial Drainage

I have observed examples of radial drainage in several parts of India. I have already discussed in detail the radial drainage system of the highlands of Madhya Bharat (Central India) in *Bulletin No. 1, National Geog. Soc. Ind.*, 1946, pp. 5-7. From these highland rivers flow out practically in all directions and thus represent a radial type of drainage. The rivers flowing to the north comprise the Chambal and its tributaries, Banas, etc., the Sindh, the Betwa and the Ken. The next important river rising from these highlands is the Son, which meets the Ganga near Dinapur.

The Damodar practically has an easterly course and joins the Ganga in its deltaic portion. The Subarnarekha is the next river which has its source in these highlands and after following a south-easterly course flows into the Bay of Bengal. The Mahanadi and its tributaries, which take their rise in these highlands, follow a somewhat easterly course.

We now consider the rivers which rise from these highlands and flow to the south. The most important comprise the Wainganga and the Wardha which become tributaries of the Godavari. Now remain the rivers which follow a westerly course and to this category belong the Narbada and Tapti. It was previously presumed that the Narbada and the Tapti show an abnormal behaviour in flowing to the west and it was not realised that these rivers form a part of the radial drainage of the highlands of Madhya Bharat (Central India). Above have been enumerated the rivers which definitely take their rise in these highlands and flow in all directions, north, east, south and west (See Fig. 1).

### (ii) Mount Parasnath

The drainage of Mount Parasnath, 4,500 feet above the sea level in the Hazaribagh District of Bihar furnishes a classical example of radial drainage which has been discussed in *Bulletin No. 18, National Geog. Soc. Ind.*, 1953, pp. 35-37. A ridge runs

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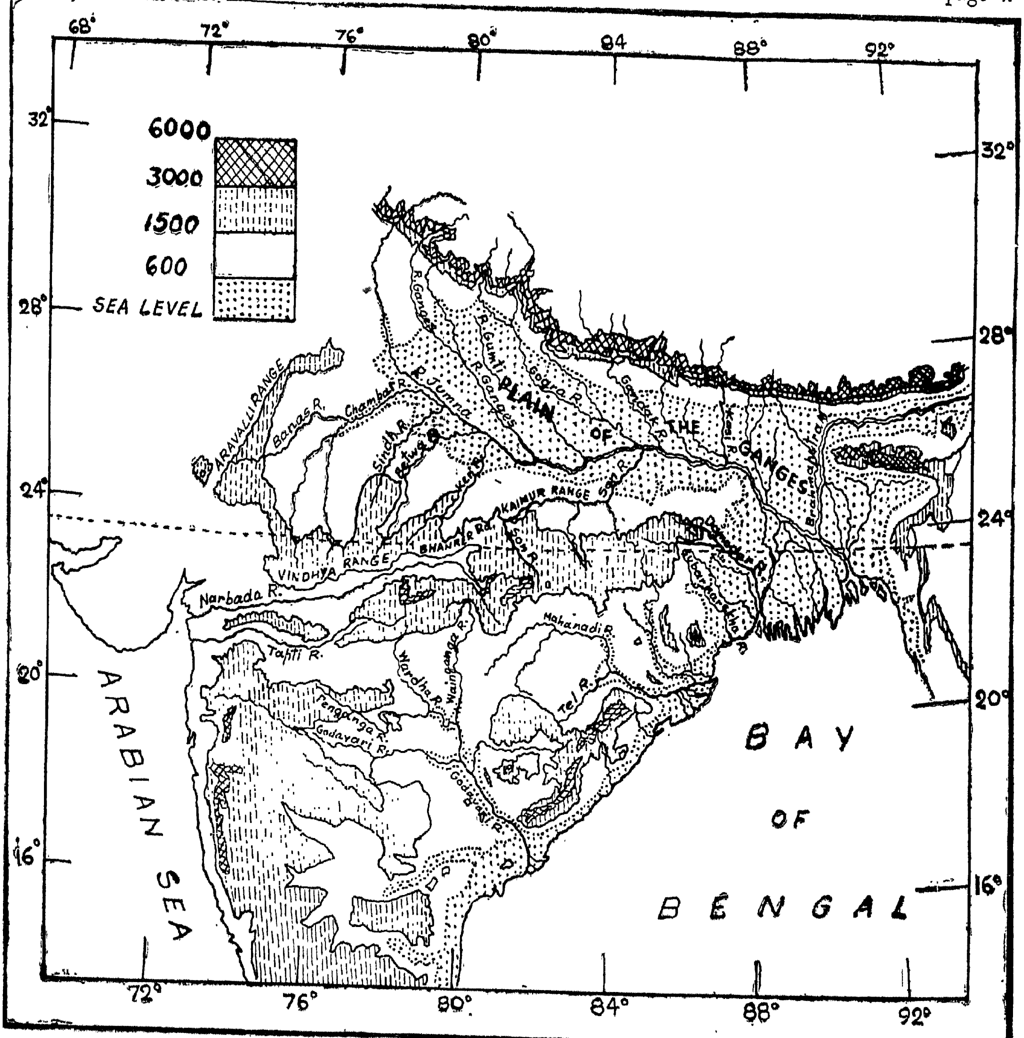


Fig. 1—Note the courses of the Chambal, Sindh, Betwa, Ken, Son, Damodar, Subarnarekha, Mahanadi, Wainganga, Wardha, Narbada and Tapti. It will be observed that these rivers rising from the highlands of Central India definitely represent a radial type of drainage.

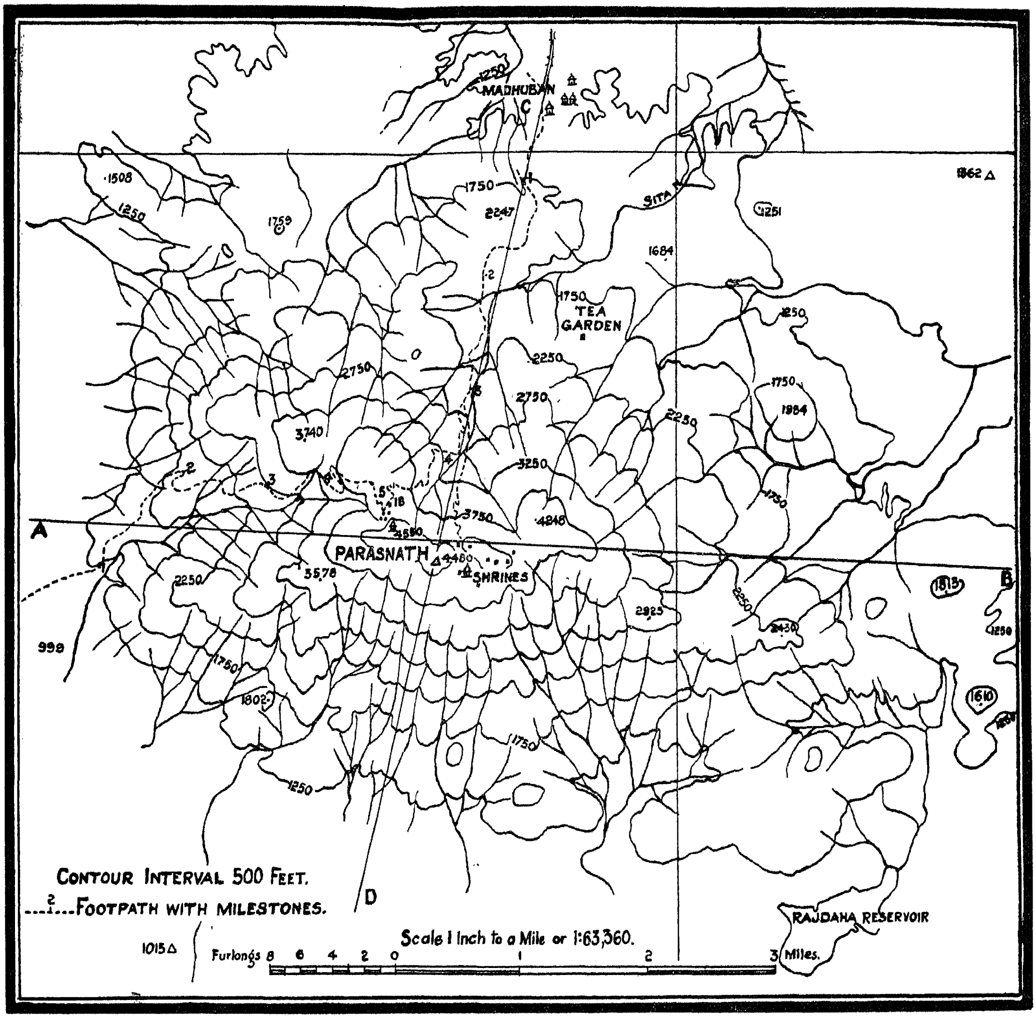


Fig. 2—Sketch-Map of Mount Parasnath. Note the maximum height of 4,550 feet above the sea level and also the ridge on which the shrines are located. From the ridge spurs are seen to descend, which enclose the valleys. The radial drainage is very characteristic. The streams flowing to the south did not have much chance of tributary development and mostly lose themselves on reaching the plateau.

practically east-west for about a mile. From this ridge streams descend in all directions (See Fig. 2). As observed from the highest point, i.e., the temple of Parasnath, three main streams are observed to descend on three sides ; on the fourth runs the main ridge. The streams flowing to the north form the head-waters of the stream marked Sita Nala on the map. The stream, which is crossed by the path to Madhuban is locally called the Gandharv Nala. The streams descending on the east and north-east form the headwaters of the Chirki Nala, a tributary of the Barakar river.

The streams descending to the south have an important characteristic. Some of them lose themselves immediately on reaching the base of the hills, while others flow for some distance on the pleateau and then lose themselves and furnish examples of inland drainage on a small scale, while a few flow into the Jamunia Nala. The streams descending on to the south are so closely located that they cannot have much chance of tributary development, while those flowing to the east and west reveal a dendritic pattern.

### (iii) Mikir Hills, Assam

The drainage of the Mikir Hills in Assam represents another example of radial drainage which has been discussed in detail in a separate communication.

Likewise the drainage of the Shali peak near Simla and the Ranchi pleateau reveal the same pattern.

## C. Centripetal Drainage of the Katmandu Valley and the adjoining Nepal Himalayas

I visited Nepal and spent the month of October, 1951 and part of the following November in investigating the Katmandu Valley and parts of the adjoining Nepal Himalayas. The Katmandu Valley is oval-shaped and is hemmed on all sides by various ranges of the Middle Himalayas. It is this feature that lends interest to the drainage of this valley (See Fig. 3). In the north there

is the Sheopuri Lekh, 8,943 feet above the sea level. In the south there is the Phulchauki Danda which culminates in an elevation of 9,050 feet above the sea level. On the east there is the Mahadeo Range, 7,133 feet above the sea level. On the west is the Chandragiri Range with a maximum elevation of 8,289 feet above the sea level.

Naturally the valley slopes from all sides to the middle, while Katmandu is located nearer its eastern end. The height of Katmandu, as noted on the degree sheet 72E, is 4,271 feet above the sea level.

## The Centripetal Drainage

*The Bagmati* :—The main river is the Bagmati which has its origin in the Sheopuri Range. Almost as far as a little above Patan the river follows a south-westerly course, but a little above Patan it trends north-west. It hugs the southern fringe of the town of Katmandu and then begins to follow a southerly course. Near Chobhar it cuts a deep and interesting gorge in limestone where characteristic landforms in this rock are to be observed. Although two gorges of the Bagmati occur, yet it must be noted that not only the Bagmati, but its other tributaries also have cut some deep valleys with precipitous sides in the soft sand-rock of Pleistocene age. It is these valleys which make the flat-topped country so highly undulating.

It may be noted that both the valleys of Kashmir and Katmandu were occupied by lakes which have left important deposits so well exposed in the river sections. South of Pharping the Bagmati leaves the Katmandu Valley and enters the Mahabharat Range where it has cut a beautiful gorge.

*The Manohra River* :—Almost running parallel to the Bagmati is the Manohra River also called Manumati which has its headwaters near and above the interesting small town of Sankhu. These dendritic streams join together above and near Nayagaon and the main stream joins the Hanumante river flowing from the east near Bhadgaon. The headwaters of the Hanumante

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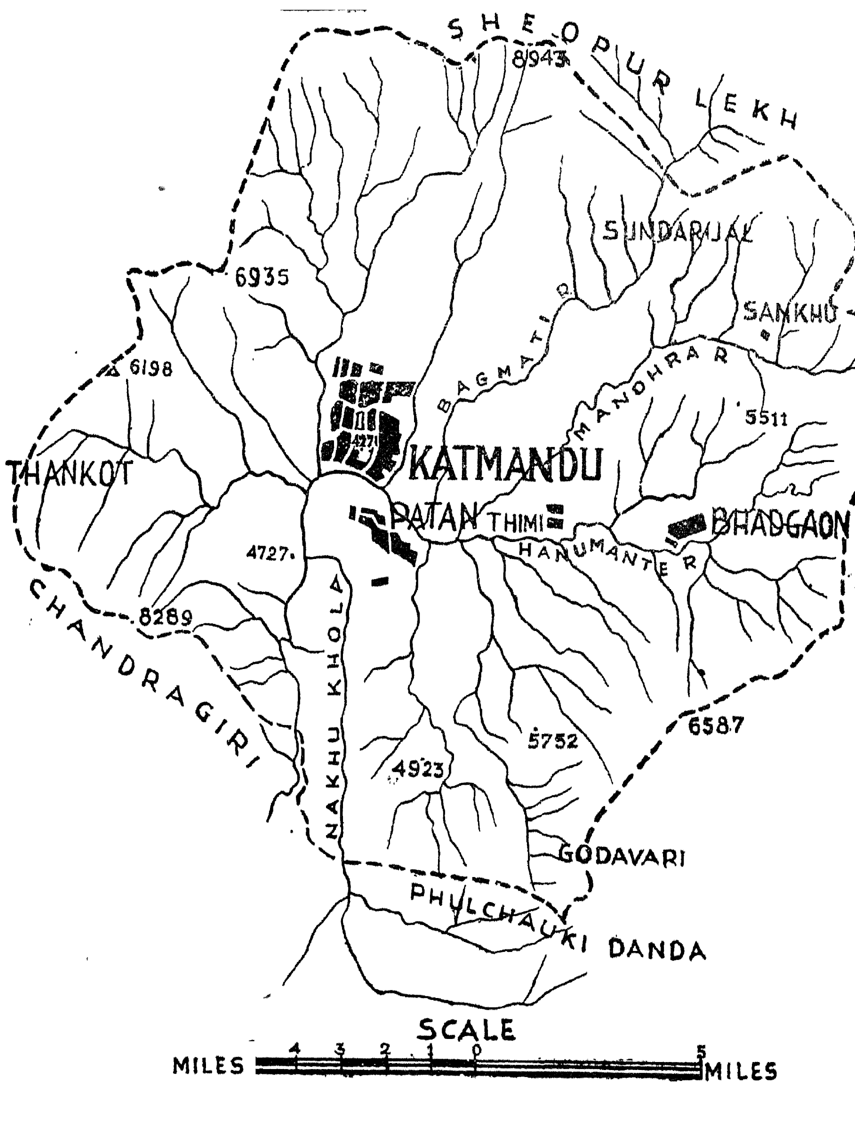


Fig. 3—Showing very characteristic centripetal drainage of the Katmandu Valley and the adjoining parts of the Nepal Himalayas. The heights of the ranges bounding the valley are shown on the map. The courses of the Bagmati, Manohra and the Hanumante should be carefully studied. It is the tributaries of the Hanumante flowing from the south and the Nakhu Khola which prove the centripetal character of the drainage. The streams descending from the west are also shown.

river have a characteristic dendritic pattern and the different streams join together to form the main stream some distance above Bhadgaon. This completes the drainage from the north-east and the east.

## The Drainage from the South-East and South

The drainage from the south-east and south is really very interesting as it reveals and confirms the centripetal drainage of the Katmandu Valley. These streams flow in a direction practically opposite to that of the Bagmati, the main river of the valley. Most of these streams discharge their waters into the Hanumante river. The course of the Nakhu Khola is very characteristic. This stream runs parallel, but counter in direction to the Bagmati for more than 8 miles. It then takes a turn first to the north-west and then to the west before it meets the Bagmati. In places, e.g., near Bungmati the watershed between the Bagmati and the Nakhu Khola is very narrow indeed.

## The Drainage from the West

There are streams flowing from the west and north-west. The former are seen to take their rise near Thankot, while the latter take their rise from above Ichangu.

There are two streams flowing from the north. The stream, which flows by the east of the city of Katmandu has its source located a little below the pass marked near point 8,943 on degree sheet 72E. It flows past Burhanilkantha and flowing past Dharmpur, Maharajganj, etc. joins the Bagmati near the south-east corner of the city of Katmandu. Another stream known as Vishnumati has its source above Sangla and flows some distance west of Katmandu before it joins near the south-west corner of the city.

Thus it will be observed from the foregoing that streams take their rise practically from all points of the compass and drain the interesting Katmandu Valley. This drainage presents

a typical centripetal pattern. It is to be noted that this type of drainage has not been described from India or Nepal before.

Besides the main centripetal type of drainage the streams of the valley illustrate also parallel type of drainage. The streams flowing to the west and east of Katmandu definitely run parallel, while the same relationship is to be observed between the Bagmati and Manohra rivers. The streams from the south also represent another example of parallel drainage.

Most of the streams, described above and descending from the surrounding Himalayas, show an interesting type of dendritic pattern. It is also to be noted that these streams flowing from all directions have dissected the Katmandu Valley which no doubt forms an elevated plain due to its infilling by lacustrine deposits. It is a curious coincidence that the lacustrine deposits in the Katmandu and Kashmir Valleys are of the same age and origin.

### (ii) The Centripetal Drainage of the Kashmir Valley

The drainage of the Kashmir Valley is again interesting and centripetal in character. The Valley, which is longitudinal in character, is 80 miles in length and about 20 to 26 miles in breadth. Near Srinagar its elevation is 5,200 feet above the sea level. The main river of the valley is the Jhelum which has its source in the Vernag spring at the foot of the Pir Panjal Range at an elevation of about 6,000 feet above the sea level. It follows a somewhat serpentinous course north-westwards as far as the Wular lake. In this stretch it receives important tributaries both from the east and the west.

From the east it receives the Sandran, the Bring and the Lidar rivers. The East Lidar river which has its source in Shishramanag and the West Lidar river which takes its rise from Tar Sar Lake have their beautiful confluence near Pahlgam.

The next important stream which joins the Jhelum is the Sind. It has its source above Sonamarg below Zojila Pass.

The valley of the Sind is very interesting and gets very constricted in the Panjal trap country and has river terraces, so clearly observed near Woyil. From the sides of the valley the ice comes down and forms interesting ice bridges across the stream. Near the mouth the waters of the Sind form a delta, which partly flow into the Anchar lake and partly into the Jhelum.

The Jhelum flows into the north-western portion of the Wular. Other rivers which flow into this large fresh-water lake are the Madmatti and the Erin. The Jhelum issues forth again from the Wular at its south-western end and follows a south-westerly course as far as Baramula which marks the terminus of the Kashmir Valley and the river enters its famous gorge.

From the west the Jhelum again receives many important rivers. In the extreme south is the Vishav river which has its source in the well-known Konsarnag lake, 2 miles in length located at an elevation of 13,000 feet above the sea level and with a reported depth of 175 to 250 feet. It is full of icefloes till mid-summer. Irrigation channels from the Vishav provide very useful irrigation to the Kulgam area. Next is the Rembiara river followed by the Sasara, Romushi, Dudhganga and the Sokhnag Rivers.

The Pohru, which drains the beautiful Lolab Valley, flows into the Jhelum near Sopor just where it again issues forth from the Wular. The Pohru is an interesting river. Its headwaters flow from the east, north and west. Below Sopor the Jhelum meanders and on its either side ox-bow lakes are to be observed which represent the deserted bends.

## D. Dendritic Drainage

Examples of this pattern could be given from several parts of India and the adjacent countries and references to some of them have already been made in the foregoing. The head-waters of the Himalayan rivers furnish excellent examples of this type of drainage. One of the very good examples of such a type is furnished by 53J/3 sheet where the streams descending from the hills represent an excellent pattern of dendritic drainage.

But a classical example of this type of drainage is represented by streams which have developed the ravine lands of the Yamuna, the Chambal, etc. (See Fig. 4). I have already made reference to this type in my article on "the Reclamation of the Ravine Lands of the Yamuna."[4] The Yamuna is generally bounded by cliffs. In places they are 90 feet high, but cliffs 30 to 40 feet in height, are quite common. The slopes being somewhat steep near the river, are admirably suited for the action of rain and running water and to begin with small gullies and ravines are formed. First the main ravine is formed and subsequently lateral ravines develop and this process goes on repeating until the land is carved into numerous dendritic ravines. After the carving of these ravines the process of integration would set in. The development of these ravines in this soft Older Alluvium of the Yamuna, the Ganga, the Narbada, etc. furnishes a classical development of dendritic pattern in its different stages. I have observed that wherever there is steep slope formed by cliffs, etc. there is ideal opportunity for the initiation, rapid development and headward extension of the dendritic type of drainage. Likewise whenever there is a change from hard rock to the soft alluvium e.g., on the southern basal slopes of Mount Parasnath, this dendritic or ravine type of drainage has developed.

## E. Types of Drainage associated with Uniclinal Structure

The region of uniclinal structure has a steep scarp on one side and it slopes gradually as a plateau and may terminate in a ghat. This type of structure is very characteristically observed in the Vindhyas south of Mirzapur in Uttar Pradesh. About 6 miles south of Robertsganj there is the well-marked escarpment of the Vindhyas about 1,300 feet above the sea level. It gradually slopes to the north for about 35 miles in a direct line until it terminates at Rajghat, 571 feet above the sea level. Two types of drainage patterns are observed : (i) which takes its rise near the escarpment and traverses the whole width of the plateau and receives tributaries. It forms the trellis pattern of drainage. (ii) The streams which descend direct from the escarpment.

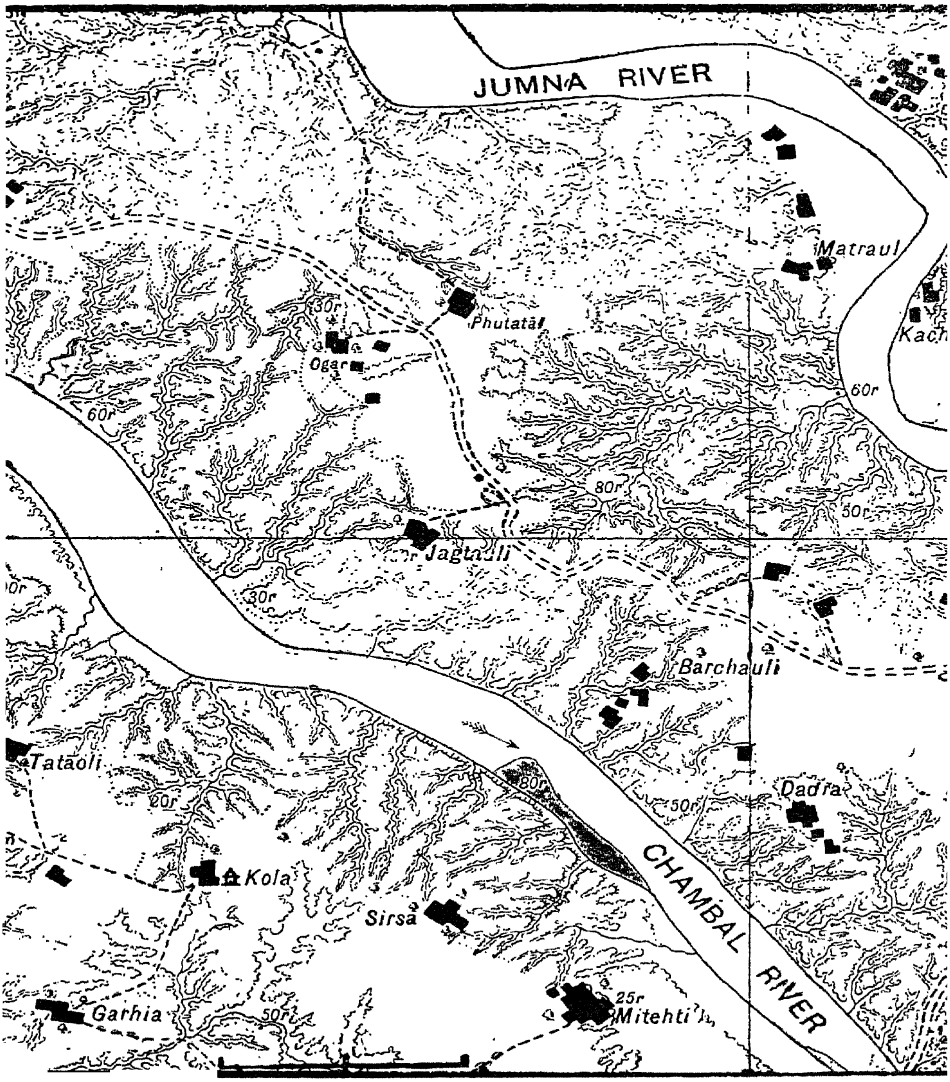


Fig. 4—Showing the characteristic dendritic drainage pattern in the neighbourhood of the Rivers Yamuna and the Chambal.

### (i) Trellis Pattern of Drainage

The plateau of the Vindhyas south of Mirzapur with a scarp exceeding 1,300 feet above the sea level in the south and a ghat 571 feet above the sea level in the north has been referred to above. The rise of the plateau is quite gentle, in places it appears almost like a flat plain.

Of course from the plateau rise butts which again reveal its general structure on a small scale. From near the edge of the plateau rise streams which flow northward and receive tributaries from the east and the west and exhibit an excellent trellis pattern of drainage. The rocks are well-bedded showing a very gentle dip hardly exceeding 5° in places. The rocks are hard sandstones metamorphosed into typical quartzites. They form cascades and waterfalls in places, e.g., the Wyndham Falls. Where the plateau terminates in the north the waters of the streams descending from it develop waterfalls. One such very good example is furnished by the Tanda Falls, about 9 miles from the town of Mirzapur. There has been a gradual recession of this waterfall and a beautiful gorge, about half a mile in length has consequently developed. During the monsoon there is a good waterfall which reduces to a trickle during the dry season. It could be developed into a storage reservoir which could be used at least for irrigating the plains below. A reservoir has been formed to the east for irrigation purposes.

### (ii) Escarpment Drainage

This is the type of drainage which actually descends from the scarp of the plateau. These streams are generally short in length and may develop hanging valleys and waterfalls in humid regions. A remarkable action of this type of drainage lies in the recession of the scarp. In India I have observed several good examples of this pattern. As noted already, a very good example is provided by the scarp of the Vindhyas, about 6 miles south of Robertsganj. The course of these streams is obsequent on the plateau, which form hanging valleys much above the

main valley. They generally fall over the scarp face and in humid regions with storage could be the source of the hydel power.

## Rohtas Plateau

Likewise this pattern of drainage is also to be observed in the Rohtas Plateau where again, besides the characteristics noted above, the streams flowing over the plateau and the scarp have been responsible for the recession of the scarp which must have existed originally on the edge of the Son. Even from its present edge there has been a recession of about 4 miles, but in some cases, e.g., in the case of the Durgauati Nala, the recession has been to the extent of about 16 miles, while in the case of the Ausanne Valley in the south it has been to the extent of at least 8 miles and now the northern and southern edges are only a little more than a mile apart.

## Westerly Drainage of Peninsular India

But the classical case of this pattern is represented by the westerly drainage of the Western Ghats. They comprise the short and torrential rivers which take their rise in the Western Ghats and discharge their waters into the Arabian Sea. South of the island of Bombay are the Amba, Kundalika, Savitri, Vashishta, Shastri, Kajvi and the Vaghotan rivers. These rivers are enumerated from north to south as far as 16°30′ North latitude. It is noteworthy that all these rivers have their courses in the Deccan Trap.

The West Coast of India owes its origin to the breaking up and foundering of the part of Gondwanaland under the Arabian Sea, but there is no doubt that the coast underwent further submergence later as is proved by a number of facts. The submerged forests of Bombay offer a clear testimony to that effect. The nature of the creeks with branching inlets represents ria type of coastline.

The Peninsular rivers also furnish examples of parallel drainage and wherever, centrally elevated regions occur, somewhat radial patterns may be formed.

## II. INSEQUENT DRAINAGE PATTERNS

### (i) Antecedent Drainage

This type of drainage including the Brahmaputra, the Sutlej and the Indus is familiar, but while investigating the Tehri Garhwal Himalaya I found that the Jahnavi or the Jadh Ganga[5] which meets the Bhagirathi near Bhaironghati, some six miles below Gangotri furnishes another example of an antecendent river which has its source in Tibet. All these rivers take their rise a considerable distance north of the Great Himalaya marking the line of the highest peaks. They represent the oldest of the Himalayan rivers and are older than the mountains through which they flow. They have kept their channels open as the uplift of the mountain and their erosion by rivers went on *pari passu*.

### (ii) Superimposed Drainage

Examples of this type of drainage are common in Peninsular India. The original drainage may have been established in the Deccan Trap which by its erosion is now superimposed in the Archaean rocks.

### (iii) Thrust Superimposed

### Drainage of the Shali Area near Simla

While examining the drainage patterns of India I came across a new type of drainage in the Himalayas hitherto unrecorded in books on Geomorphology. It is the drainage of the Shali area near Simla. W. D. West[6] has described the structure of the area but made no reference to its drainage. In this case the Chail series of Purana age has been thrust as a flat sheet on younger Tertiary rocks and the underlying Shali series presumably of Krol age. The Shali peak is 9,406 feet above the sea level and is composed of upper Shali limestone and quartzite. From this peak streams descend in a radial pattern. The streams flowing to the east, south-east, south and west form tributaries of the Nauti Khad, while the streams running to the north flow

into the Sutlej. There is no doubt that this drainage must have been originally established in the oldest rocks of the Chail series. It was gradually denuded away and the drainage established itself on the underlying younger rocks of Tertiary age and also on the Shali series. The physical regions and topography as also the geology of the area have been described in a separate communication. Likewise a concise summary of the elements of structure has also been given.

The drainage of this region is represented by the Sutlej and its main tributary the Nauti Khad. Their courses are interesting and their account has been included in the original communication. It is the work of the Sutlej and its tributaries which has revealed this new type of insequent drainage (See Fig. 5).

## Sequence of Events

The sequence of events in this region is as follows. The rocks of the Shali series, tentatively referred to Krol Nappe, were in position before the deposition of the Sabathu beds of Lower to Middle Eocene age. Then the Dagshai beds of Lower Miocene age were deposited on them. Apparently during the second phase of the Himalayan uplift about the middle of the Miocene the Chail series were pushed from the north as a practically flat sheet covering the pre-existing Shali series and the Tertiary rocks. In post Mid-Miocene times the drainage of the region comprising the Sutlej and its tributaries began to establish itself on the Chail series.

By the action of the rivers and rain the cover of the Chail series was denuded and the drainage began to establish itself on the Tertiaries and ultimately on the underlying Shali series of Krol age. The region with the third phase of uplift of the Himalayas must have been further elevated and it must have attained almost its final elevations at that time. The establishment of the drainage and its subsequent superimposition on to the underlying younger rocks therefore dates back to the close of the Tertiary or the beginning of the Quaternary Era.

## (iv) Migratory Type of Drainage

I have already shown in my work on "Westerly Drift of Rivers of Northern India and Pakistan" that no reference is found in important works on Geomorphology about this drift of rivers, particularly those of India and Pakistan. The westward drift of rivers of Northern India even during historical times is very remarkable. It is noteworthy that such a migration is observed in the case of practically all rivers of Northern India and Pakistan. This marked westward migration is to be observed in the case of the Brahmaputra, the Bhagirathi in Bengal, the Kosi, the Gandak, the Gogra, the Son, the Sutlej, the Ravi and the Indus. For details the interested reader is referred to the work cited above.[7] In some cases this migratory movement has been to the extent of 120 miles or even more. It is striking that in this westward drift the rivers are shifting to the higher lay of the country.

Although it has been shown that practically all rivers of Northern India and Pakistan show this westerly migratory movement, but the Kosi indeed provides a classical example of this type of migration. It has shifted to the west by about 75 miles during the last 200 years (See Fig. 6). This river by its floods and shifting of its course has played a regular havoc almost every year with the land and people of Bihar and it has rightly earned the title of the 'Sorrow of North-Eastern Bihar'. It has been undergoing a steady westerly movement for hundreds of years. This drift is attributed to secular causes and the law which is applicable to winds and ocean currents holds good in the case of river currents also.

The next river is the Gandak which meets the Ganga near Patna. The Burhi (old) Gandak which runs roughly parallel to and east of the Gandak is believed to mark the old channel of the main river (See Fig. 7). This represents a westward migration of the river to a distance of about 90 miles in a direct line as judged by the distance between the confluences of the Burhi Gandak and the Gandak with the Ganga.

A little farther to the west the Son joins the Ganga from the south. It is also noteworthy that the confluence of the Son and the Ganga has been gradually shifting and the deserted channels of the Son are to be observed between Bankipur and Dinapur and even as far as Patna. The ancient Patna or Patliputra was a very flourishing city on the Ganga till the 5th century A.D. It is stated to have been located near the confluence of the five great rivers, viz., the Gandak, the Gogra, the Ganga, the Son and the Punpun. Some of these rivers do not join the Ganga at Patna and their confluences have been shifted by many miles. The Gogra now meets the Ganga many miles west of Patna.

I have already referred to the easterly drift of the Son between Rohtas and Dehri in the Shahabad District of Bihar.[8] It originally flowed below the pleateau of the Vindhyas in this region, but it has gradually drifted to the east and its present course is some miles away from the edge of the plateau.

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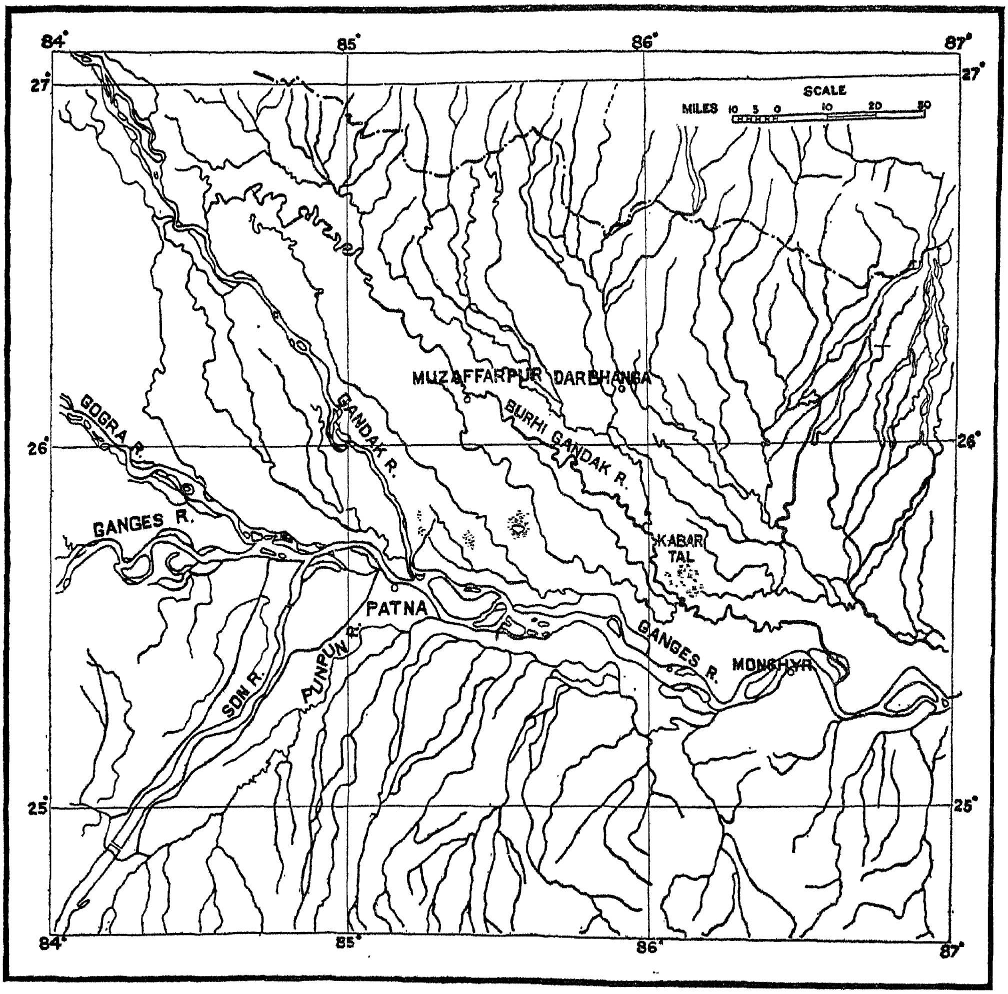


Fig. 7—Showing the courses of various rivers near Patna. Note the confluence of the Burhi Gandak, which represents an old channel of the Gandak, with the Ganga. Likewise the confluences of the Gogra, the Son and the Punpun with the Ganga have all shifted. Note the streams flowing from the south which run parallel to the Ganga for a considerable distance before joining it.

## Part II : The Development of Landforms in the Himalayas.

### The Himalayan Landscape

No doubt landforms are of great importance to a geographer as they play a fundamental role in determining man's activity. The influence of the Himalayas in determining not only its own climate, but that of the plains of India to the south and the plateau of Tibet to the north would be familiar to any serious student of geography. It is well known that climate determines products of a region. Naturally human activity in the Himalayas is certainly different both from the plains of India and Peninsular India. The agriculture in the Himalayas on terraced fields, method of irrigation, where possible, the habitat of the people, their trade, their communications are all different from the regions, referred to above.

There is, therefore, no doubt about the importance and interesting character of the study of landforms, but those of the Himalayas remain unparallelled in their beauty and grandeur. Here occur the highest peaks of the world, some of them eternally covered with silvery snow giving rise to mighty glaciers and rivers developing very remarkable landscape by their action—a landscape which if you might see even from a distance, e.g., the view of the snow-peaks against the Alpine or red glow of the morning or the evening sun might leave a lasting impression on the mind.

Here the relief, the geology, the structure, process and stage all present the greatest variety and, no doubt, reveal some very interesting material for study and thought to a student of Geomorphology, but the work in the Himalayas is strenuous and exacting, especially when carried out with trifling resources. The importance of geographical research and exploration is not realised in this country. The foreign countries send out costly expeditions, well-equipped in all detail for the sake of mountaineering and exploration, while in India this aspect has been

scruplously neglected. Perhaps the recent conquest of Mount Everest may provide some stimulus. Tensing is trying to organise an Institute of Mountaineering at Darjeeling. As noted in the foregoing I have made an endeavour to explore some regions in the Himalayas. I have therefore chosen the subject of "The Development of Landforms in the Himalayas" for Part II of my address. This has been done also with a view as the study of Geomorphology has remained neglected in India, but it has been my regret that, restricted as I am in matter of space and time, it has not been possible to do justice to the subject it deserves.

## Landscape as a function of Geology, Relief, Structure, Process and Stage

In my earlier communications I have already discussed that the landscape is really a function of five variable factors including Geology and Relief together with Structure, Process and Stage as suggested by W. M. Davis. I have already emphasized that structure under no circumstances can convey a proper idea of the geology of the region which does play an important role in the development of the landscape. Study of landforms in the Himalayas has revealed that other factors being the same geology, as shown in the sequel, does bring about a remarkable difference in the development of landforms, e.g., those developed in the granite and the quartzites are absolutely different from those developed in the schists, phyllites and slates.

The relief is equally important. There is no doubt that the giant peaks of the Himalayas have built unparallelled landscape as a result of relief. The landforms developed in the same rock in lowland regions are absolutely different from those of a high mountain region.

## Structure

The structure of the Himalayas is really complicated. The nappes have been pushed forward for considerable distances and thrust over other rocks. But the dip-slope and escarpment feature, so characteristically observed in the Siwalik Range, is also

to be observed in the Middle as well as in the Great Himalaya.. I observed this feature so commonly in the Tehri Garhwal Himalaya in my trek between Tehri and Gangotri. The same feature was observed in the Pir Panjal Range overlooking the Kashmir Valley and also in the Great Himalaya including Mount Everest, etc. However, I have given a concise account of the structure of different parts of the Himalayas in my "India, Part I, Physical Basis of Geography of India" (Nand Kishore and Bros), 1945, pp. 257-263 and the interested reader is referred to it.

## Process

In the Siwalik Range the action of rain and running water are the dominant agents of denudation in developing the landscape, especially in carving out the ravines, on the scarp side.

In the Middle or the Lesser Himalayas besides the two agents of denudation, referred to above, the action of frost also becomes important and this becomes responsible for developing talus and talus streams. As a result of jointing and gravity rockfalls also occur, but they are still more characteristic of the Great Himalaya. During winter even in the Middle Himalayas there is precipitation in the form of snow, and snow-beds, especially in the valleys, are to be observed up to the middle of May.

## Stage

The study of river terraces has revealed that the base level conditions are reached when the region undergoes further upheaval responsible for its rejuvenation and another subcycle is initiated and vertical corrasion commences again. In places six to seven such terraces were counted, but three to four are common which were formed during the Recent and Sub-Recent Periods. From this I have concluded that the Himalayas underwent important intermittent uplift even during the Recent Period, in other words even after the third phase of the Himalayan uplift at the end of the Tertiary Era. This in other words corroborates the testimony we already have from the intensity and frequency of the earthquakes in the Himalayas and the desiccation of the Tibetan

lakes that the Himalayas are still undergoing uplift but intermittently.

For purposes of study of landforms the Himalayas have to be classified geographically :—

(i) The Siwalik Range with a maximum elevation of about 4,000 feet above the sea level. It has a maximum width of 30 miles in the western parts.

(ii) The Middle or the Lesser Himalayas. These have an elevation of about 12,000—15,000 feet above the sea level. This zone is about 50 mils in width and comprises a number of ranges.

(iii) The Great Himalaya. This range has an average elevation exceeding 20,000 feet above the sea level. It consists of a single range, about 15 miles in width but its spurs projecting to the south extend for another ten miles into the Lesser Himalayan region.

## Landforms of the Siwalik Range

I have made a detailed study of the development of the landforms in the Siwalik Range[6] adjoining the Doon Valley and it is remarkable that what was observed in this region is to be seen throughout the entire length of the range. This region is crossed by two important roads, namely the Dehra Dun-Saharanpur and the Chakrata-Saharanpur Roads. It reveals in a characteristic manner the dip-slope and scarp faces. The former is covered with dense Sal *(Shorea robusta)* forest, while the much steeper scarp face is highly ravined. The base of the Siwalik Range above the plains near the village of Mohan is about 1,500 feet above the sea level, while the highest point Amsot is 3,140 feet above the sea level. The maximum width of the Siwalik Range in this region is about 10 miles. Its trend varies from W.N.W.-E.S.E. to N.W.-S.E. In places the water divide is well-defined, while in others it is very irregular with the result that the drainage on either side is overlapping. In places the range is traversed by longitudinal valleys.

Fig. 1—Cliffs facing south above the right side of the road with pyramidal and needle-like peaks. The cliffs are almost perpendicular and are further ravined by minor tributaries and are grown with grass and small bushes. Photo taken from 9/5 mile on the Dehra Dun-Saharanpur Road.

*Photo : H. L. Chhibber.*

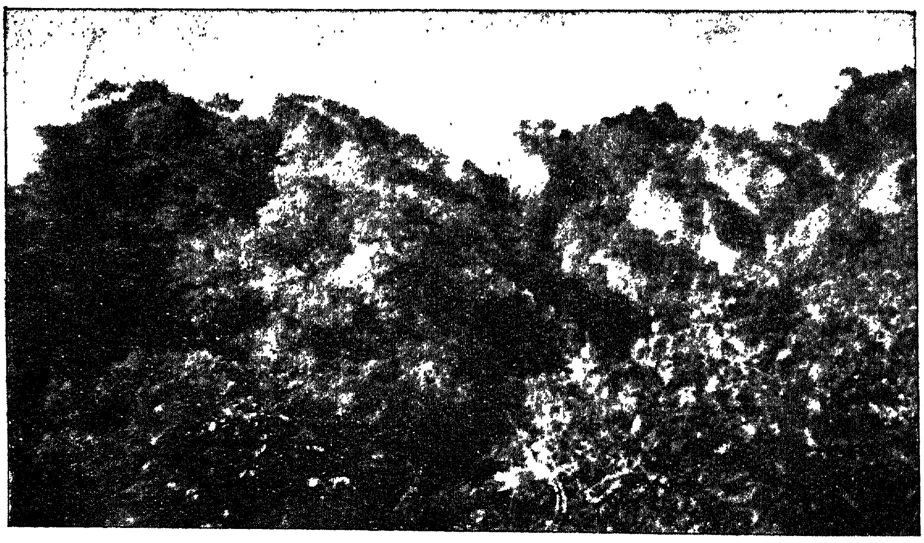

Fig. 2—As a result of erosion a series of dip and scarp slopes are to be observed, e. g., on the right side of the road a little less than a mile below the Timli or Dararit Pass *en route* to Saharanpur.

*Photo : H. L. Chhibber.*

The climate of the region, referred to here, is discussed in the communication cited above. For purposes of erosion and the development of landforms the year could be divided into two well-marked seasons : *(a)* June-September and *(b)* October-May. It is noteworthy that most of the erosion takes place in four months of June-September, which plays an important part in the development of landforms in the region.

References to the geology and relief of the region have been made in the communication cited above. The structure is characterised by asymmetrical anticlinal folding with the development of gentle dip-slopes and steep escarpments. The vegetation on the two slopes has been described and it is note worthy that on the scarp side it suffers a remarkable change, both in its composition and density. *Shorea robusta,* which is prolific and has a majestic growth on the dip-slope facing north practically becomes insignificant on the scarp side. The Siwaliks on the escarpment side form high cliffs with sharp peaks. From the peaks descend spurs which are really very sharp-edged. In places the form of peaks is pyramidal. (See Plate 1 Fig. 1 ), conical and almost needle-like. The steep scarp slopes of the Siwalik Range are practically bare and deeply ravined and this results in the menace of soil erosion.

Near the Kali Temple on the Saharanpur side of the Timli or Dararit Pass, water level in a masonry well at an elevation of 2,100 feet above the sea level in October, 1950 was found to be only eight feet from the surface. Landslides in the soft unconsolidated rocks occur very frequently. The Siwalik Range shows a beautiful serrated crest (See Plate II Fig. 1).

The hills in the neighbourhood of Hardwar form elongated ridges running in an E.N.E.—W.S.W. or N.E.—S.W. direction, the elevation varying from 1,301 to above 2,000 feet above the sea level. On the sides of dip slopes a series of 3-4 sandstone cliffs, almost perpendicular, are to be observed. It is interesting to observe a series of re-entrants in these cliffs. Two small falls were observed in the thickly-bedded sandstones while

descending from the Mansa Devi Temple to Suraj Kund. Water courses are generally bounded by cliffs. Below Hardwar, where the Ganga enters its plain career, its channel is highly braided with numerous wooded islands, almost simulating deltaic conditions.

## Landforms in the Middle Himalayas

As a result of normal erosion deep gorges have developed in hard rocks like the granite and the quartzites. The rivers descend through transverse and longitudinal valleys. In the former case the gradient being steeper the foaming water rushes forth practically as a torrent with the result that deep narrow gorges are formed, while in the longitudinal valleys the waters run more placid generally forming more open and broader valleys. In the schists and the phyllites broad open valleys are formed. The soil being suitable and the slopes being somewhat gentle they are generally terraced for purposes of cultivation and consequently the settlements also occur. In the region of the softer rocks river terraces (See Plate II Fig. 2) commonly occur. The hanging valleys and waterfalls are also formed, but these are even more characteristic of the Great Himalaya. As a result of tectonic movements interesting incised meanders have been formed. The talus and talus streams are also commonly observed, which tend to grade themselves.

Landslips, landslides and rockfalls commonly occur, the first two in the region of soft rocks, while the third are characteristic of more resistant rocks. These various features have been discussed in detail in the sequel.

## River Terraces

River terraces (See Plate III) are an important landform bordering the rivers and streams in the Himalayas. I have investigated the River Terraces of the Yamuna and the Tons Nadi in the Doon Valley[7] and also of the Bhagirathi between Gangotri and Tehri[10]. The height of the terrace below Gangotri must be 9,000 feet above the sea level, while that of the lowest

Fig. 1—The serrated top of the Siwalik Range as observed from the Herbertpur-Pāonta road with rapeseed and sugar cane fields in the foreground.

*Photo : H. L. Chhibber.*

Fig. 2—Showing the face of the highest terrace above the road behind Dhanpur which runs on the lower terrace with the convex slopes of the hills composed of the schists in the background, *en route* to Nagini.

*Photo : H. L. Chhibber.*

Fig. 1—The terrace above the left bank of the Bhagirathi opposite Nagun. The lower portion is covered with vegetation, while the upper forms the cliffs. It has been etched out by "hanging" water courses. This upper terrace runs southward for a considerable distance. A little farther downstream of Nagun two lower terraces are to be observed.

*Photo* : *H. L. Chhibber.*

Fig. 2—Showing well-marked river terraces in the Bhagirathi valley above Sarot. The photograph is taken from a little above Sarot looking upstream.

*Photo* : *H. L. Chhibber.*

terrace near Tehri is above 2,000 feet above the sea. These terraces are interesting and important from economic and human point of view. They definitely mark the stages when the river at one time had reached its base level of erosion and was then rejuvenated and commenced its vertical corrasion again. In places a series of these river terraces are to be observed. In one place as noted already, as many as six to seven were observed, but three to four commonly occur. In some places these terraces are matched, while in others they are not paired. The river terraces are best developed in the region built of the schists, phyllites and slates, while they are certainly rare in the granite and quartzite country, thus showing the influence of the geology on the development of landforms.

### Incised Meanders of the Bhagirathi

The meanders of the Bhagirathi near Mali Dewal (30° 25′ 32″: 78° 26′ 50″) ( See Plate IV, Fig. 1 ) are definitely incised. Similar incised meanders were observed near the confluence of the Bhagirathi with the Salalam Gad, etc. They are V-shaped, U-shaped and inverted U-shaped which may be narrow or acute or they may be broad. The river flows through a deep gorge, the sides of which may be 400-600 feet above the bed of the river. It may culminate in a flat terrace above.

### Alluvial Fans

The small tributary streams of the Bhagirathi, especially those which have steep courses, have well-marked alluvial fans at their terminus. They were observed *en route* from Narendranagar to Tehri, particularly near Nagini. They were again observed between Tehri and Dharasu.

### Talus Streams and their Grading

In the case of hard rocks like the quartzite and the granite, which are well jointed, and owing to the action of frost, scree material, especially as a result of rockfalls, is very commonly observed. Here talus streams occur on the slopes as well as in

the water courses. Sometimes a water course was observed to be literally choked with blocks of these rocks. Talus streams of quartzite were observed on the slopes near Sainj (30° 46′ 12″ : 78°35′ 15″) above the right bank of the Bhagirathi. These will of course tend to grade themselves.[10]

## Landslips and Landslides

In the region of softer rocks comprising the schists and phyllites, landslips and landslides, sometimes hundreds of feet in height are to be observed. These soft rocks decay easily and the steeper slopes are scarred by large landslides making the slopes very precipitous, almost vertical or even concave. The bare face is further ravined by the action of rain and running water.

Sometimes huge landslides might occur and might blockade the course of the river and dam it into a lake which might ultimately overflow and wash away the barrier causing serious floods below.

## Development of Landforms in the Bhagirathi Valley

I have already stated that the Himalayas are traversed by several important rivers which have carved out interesting valleys. One such main valley is that of the Bhagirathi which I have investigated carefully between Tehri and Gangotri. The account given below will apply generally to similar valleys. The Tehri-Gangotri region covers a distance of a hundred miles by road. The various factors which affect the development of landforms have been referred to above. The relief gradually decreases as one proceeds downstream. Near Gangotri the bed of the Bhagirathi is more than 9,000 feet, while in the neighbourhood of Tehri it is about 2,000 feet above the sea level. With regard to structure the nature of the divisional planes has been noted in each case. There is only small variation in process, while the stage remains the same. Of all these factors the influence of geology appears supreme as with the change of rocks there is the alteration in landforms.

Fig. 1—The incised meander near Mali Dewal. The photograph was taken from the road a little above Mali Dewal looking north.

*Photo* : *H. L. Chhibber.*

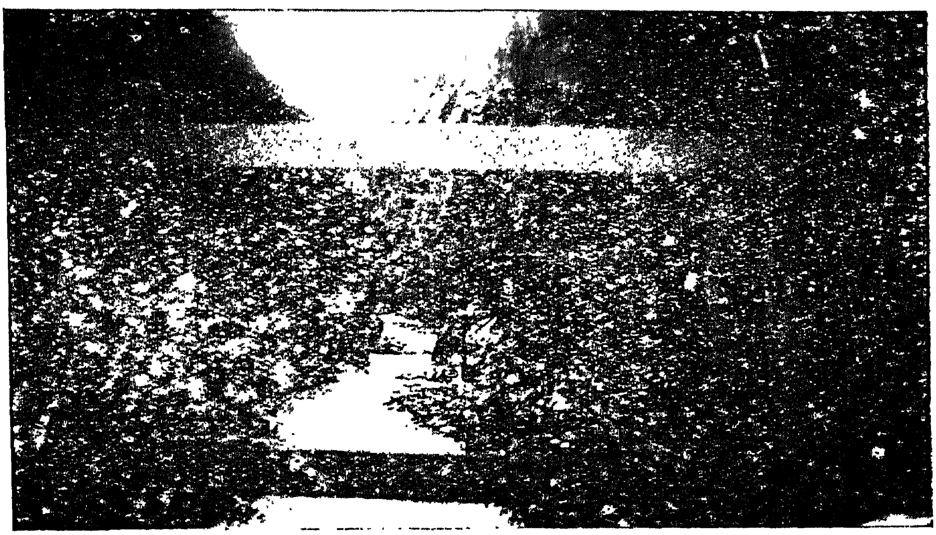

Fig. 2—Gorge of the Jadh Ganga from the iron bridge looking upstream. The gorge has been carved out in the granite.

*Photo* : *H. L. Chhibber.*

To face p. 25.

Fig. 1—The Quartzite hills behind Gyanju near Uttarkashi.
*Photo* : *H. L. Chhibber.*

Fig. 2—The Bhagirathi in the upper portion of he quartzite gorge below Dunda.
*Photo* : *H. L. Chhibber.*

## Landforms near Tehri

The peaks in the neighbourhood of Tehri tend to be pyramidal and the spurs have convex slopes, but where traversed by streams, they are rendered concave. The range, on which Pratabgarh is situated, has a sharp-crested ridge which runs practically flat for some distance to the south-east and farther beyond has a few pyramidal peaks which may be rounded occasionally. The upper portion is definitely composed of the quartzites with steep sides. Crags are common.

The phyllites below form flat tops and descend with spurs having convex slopes. On the spurs settlements are located. Water courses have carved out deep valleys. In the tributary valleys huge landslides, hundreds of feet in height, are to be observed as a result of gravity, soliflucation, etc. The junction of the schists, phyllites and the quartzites can be observed from a change in the landforms in the two formations.

The peaks in the schists behind Godi are somewhat rounded or roughly pyramidal with a somewhat flat cleavage face and with a scarp face on the other. The spurs descending from the peaks are sharp-edged with low peaks rising in places.

## The Gorge of the Bhagirathi in the Quartzites

Near Nalapani above Dharasu the Bhagirathi has cut a vary narrow gorge in the quartzites with very precipitous sides, more than 3,000 feet in elevation (See Plate V, Fig. 2). It indeed presents a great contrast to the generally open vally of the schists and phyllites observed between Tehri and Dharasu and is due to the resistant character of the quartzites. Even the small water courses observed above the left bank are almost perpendicular. It is remarkable that no river terraces are to be observed in this gorge. Here no cultivation nor any habitation was observed in the lower part of the gorge. Only sparse pine trees are to be seen.

## Dip and Scarp Slopes forming sides of the Tributary Streams

It is noteworthy that near Suki, Jhala, etc. *en route* to Gangotri a remarkable feature was observed that one side of the stream shows dip-slope, while the opposite side is composed of the scarp slope. This was observed in a characteristic manner with regard to the Son and the Sian Gads taking their rise from the glaciers of the Great Himalaya. The southern face of the Pilgau Dhar above Bhelatipri showed the same feature (See Plate VI, Fig. 2).

At Harsil above the left bank of the Bhagirathi flat cleavage slopes of the metamorphic rocks dipping at steep angles are to be observed, while on the opposite side steep scarp slopes are to be seen.

## The Granitic Region

I have observed several granitic regions in India, Burma and Europe, but the granite scenery in the neighbourhood of Gangotri and Bhaironghati remains unique, perhaps on account of its elevation in the Great Himalaya, and the process connected with a young active river. As observed by flat river terraces the river has been rejuvenated several times. As soon as its action was arrested by attaining the base level of erosion it received a great jerk and was made to commence its work of vertical corrasion again.

The difference in the scenery of the schists and the granitic country reveals how geology influences the development of landforms. In the granitic country a very constricted gorge with overhanging cliffs in places is to be observed and it would be difficult to find a more suitable text book illustration than the gorge of the Jadh Ganga (See Plate IV, Fig. 2) which meets the Bhagirathi near Bhaironghati, while, as noted above, broad valleys are are formed in the schists and phyllite country, e.g., between Tehri and Dharasu, (See Plate VI, Fig. 1, Plate IX, Fig. 2 and others) etc.

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Fig. 1—View of the broad and braided bed of the Bhagirathi looking upstream (Photo taken from the descent to Jhala).

*Photo* : *H. L. Chhibber.*

Fig. 2—Southern face of the Pilgau Dhar above Bhelatipri, showing the scarp and the dip-slope.

*Photo* : *H. L. Chhibber.*

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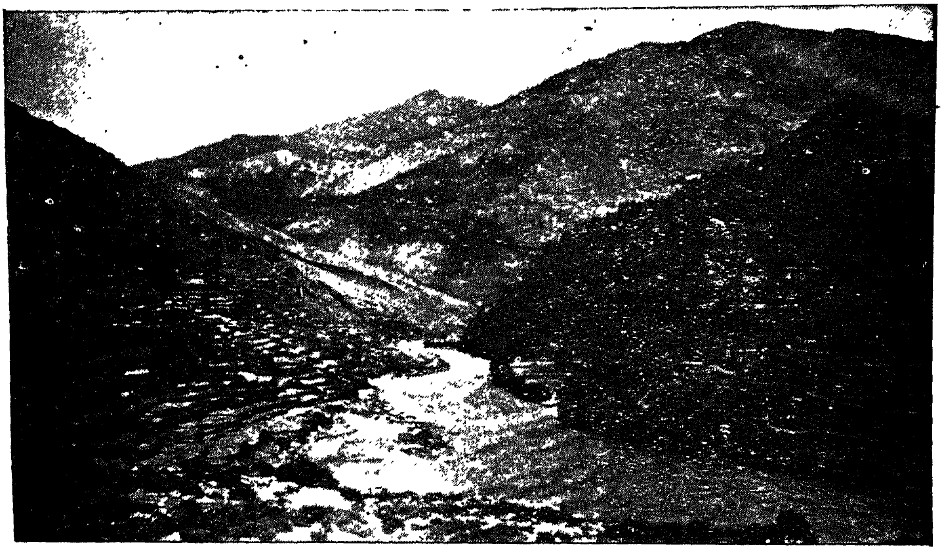

Fig. 1—The Bhagirathi Valley above Kumalti from below the Kumalti Gad looking upstream, N. E.-S. W. longitudinal bend.

*Photo* : *H. L. Chhibber.*

Fig. 2—The Bhagirathi Valley near Saunra below Sainj

*Photo* : *H. L. Chhibber.*

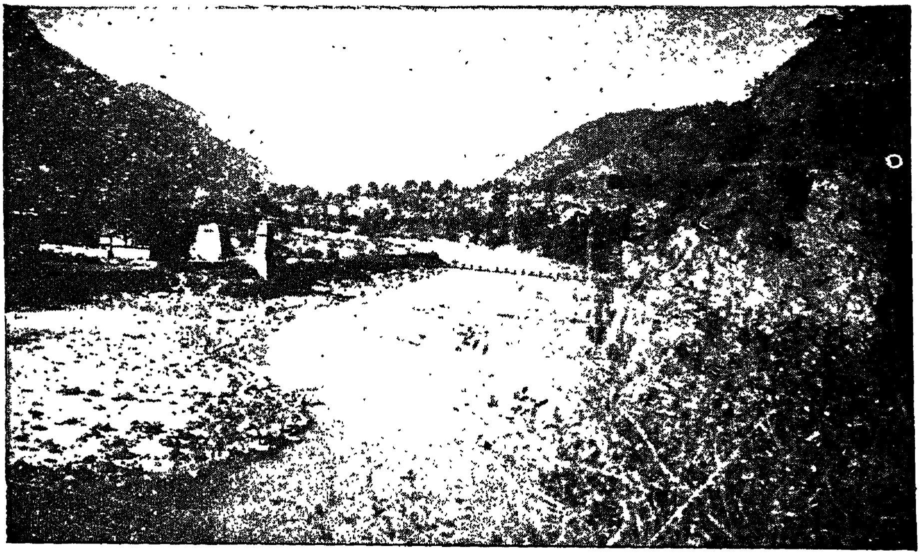

Fig. 1—The Bhagirathi at Uttarkashi looking downstream with the Suspension Bridge. Note the broad open longitudinal valley in quartzites.

*Photo* : *H. L. Chhibber.*

Fig. 2—Dip and scarp slopes of the quartzites above the right bank of the Salalam Gad behind Barethi village near Uttarkashi.

*Photo* : *H. L. Chhibber.*

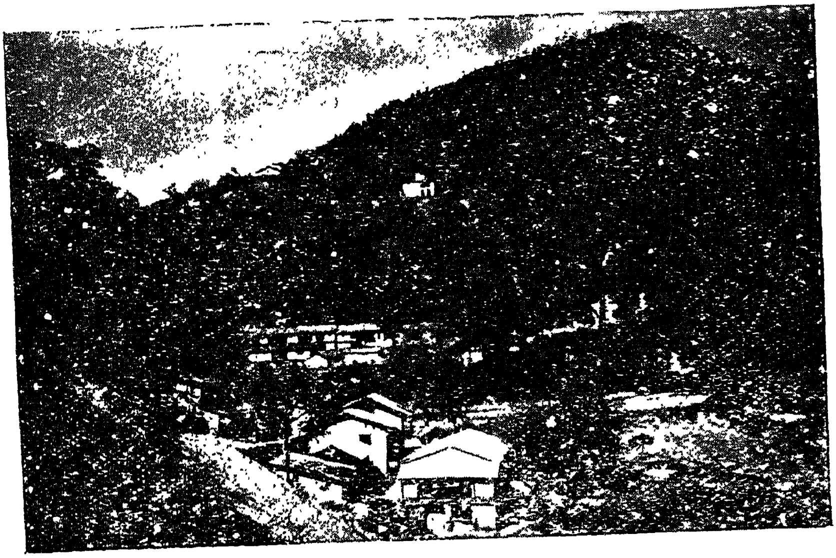

Fig. 1—Dharasu village from the road, a littte downstream. Note the form of the hill composed of the schistose rocks in the background.

*Photo* : *H. L. Chhibber.*

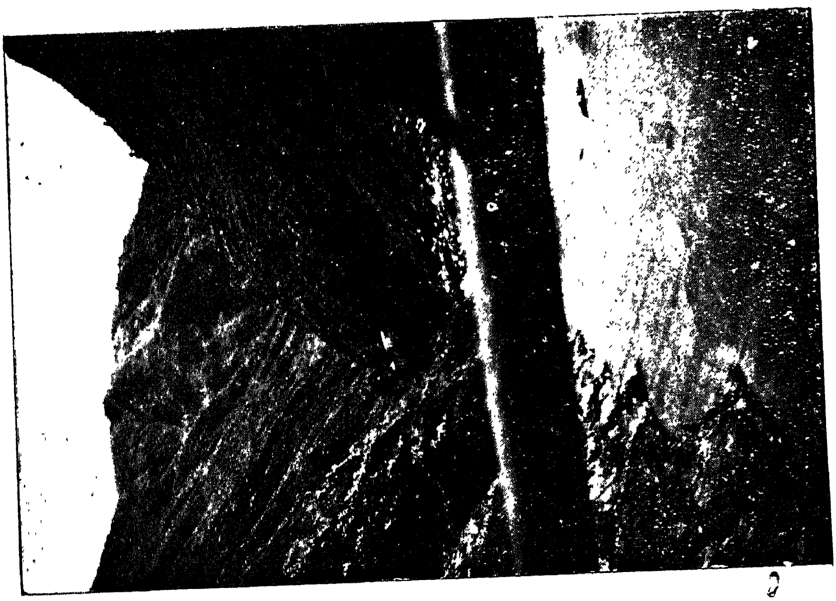

Fig. 2.—A View of the Bhagirathi with its valley looking upstream from the Suspension Bridge at Tehri. It is composed of the schists and the phyllites.

*Photo* : *H. L. Chhibber.*

## Longitudinal Valleys in the Himalayas

### Kashmir Valley

While discussing the landforms of the Himalyas I must not omit to refer to the important longitudinal valleys in the Himalayas. Commencing from north-west there is the picturesque valley of Kashmir which is the largest of its kind. As noted already, it is 80 miles in length with a maximum width of 26 miles. The Jhelum takes its rise from the spring of Vernag (Verinag) at an elevation of about 6,000 feet above the sea level, while the town of Srinagar is 5,200 feet above the sea level. The valley is bounded by the Middle Himalayas, but it is practically flat and the rivers descending from the Himalayas develop broad and braided courses and the Jhelum itself follows a very serpentinous course. It is noteworthy that part of the valley is occupied by lakes which must have been more extensive in the past. I am definitely of the opinion that the Wular and the Dal originally formed one sheet of water and the intervening Anchar, Manasbal lakes, etc. represent the vestiges of that sheet of water.

From the valley flat-topped Karewas rise in places. The space would not permit me to deal with them here.

### Doon and other Valleys

Next important valley is the Doon Valley which is bounded by the gentle dip-slope of the Siwaliks in the south, while in the north it is hemmed practically by the Mussourie Range. Such valleys are very common in this part and sometimes a longitudinal valley may occur in the Siwalik Range itself.

### Katmandu Valley

The third important valley is the Katmandu Valley which has an area of about 144 square miles and is hemmed in all sides by ranges of the Middle Himalayas attaining elevations exceeding 8,000-9,000 feet above the sea level. From these ranges spurs descend on to the valley and in the embayments

cultivation is carried on. During October it appeared like a vast expanse of paddy. Katmandu, as noted already, is situated at an elevation of 4,271 feet above the sea level. There is no doubt that during the Pleistocene period the valley was occupied by a lake and by its infilling practically a level plain of sand-rock was formed. This was dissected subsequently by rivers and the streams with the development of somewhat broad and deep valleys ; the country today is highly undulating. Islands of limestone and other rocks are to be found in the valley throug which the Bagmati has cut moderately deep gorges and in places the hills of Chobhar, etc. occur.

## Landforms in the Great Himalaya

Some of the landforms enumerated in the case of the Middle Himalayas are also to be observed in the Great Himalaya, but the elevation being greater, here precipitation in the form of snow is much greater and consequently the action of snow and ice is very characteristic of this region. Glaciers, both longitudinal and transverse, develop and carve out glaciated topography. Most of this region is generally clad with snow and is too cold, except in the valleys, for cultivation and human nomadic habitation. Alpine pastures occur in suitable places where the people may take their sheep and goat and even cattle in the lower regions for grazing during summer.

In this region glacial lakes are common. Rock basins, originally carved out by former glaciers, may occur at much lower levels than where glaciers descend today.[11] This indicates the extent of recession of the glaciers. For example, the Gangotri glacier has its snout at 12,777 feet above the sea level, while the glacial lakes representing old rock basins occur near Dharali at an altitude of 9,200 feet above the sea level. No glaciers occur in this neighbourhood today.

The hanging valleys and waterfalls are more common in this region and some of the latter may be 200 feet or even more in height. However, not all hanging valleys may be of glacial

origin. In this region the action of frost is very severe and where the rock is jointed and the joints dip with gravity, rockfalls, sometimes huge in size, are very common. For example, they have caused considerable damage at Gangotri. The huts are sometimes carried away and generally a stone fencing is placed round a hut for purposes of safety.

This region comprises an endless vista of mountains or a chain of peaks, about 20,000 feet or more in elevation above the sea level and not infrequently culminating in a pointed majestic summit. The peaks comprise massifs, great rock-peaks, pyramidal peaks and white domes or beautifully shaped snow-cone summits. Sometimes there may be twin peaks or the main peak may have its satellites. The peaks are connected by dazzlingly white sharp or knife-edged ridges with cols, 18,000 feet or more in elevation.

Mount Everest, the loftiest peak in the world, forms an imposing massif when viewed from the north, although the northern face is built of a series of dip slopes, while the southern face is composed of scarps. The Kanchenjunga massif with five peaks rises up in a series of almost vertical precipices and battlemented ridges. Mount Godwin Austen or $K_2$, 28, 278 feet above the sea level, representing the highest peak of the Karakoram, builds a steep sided cone. Sometimes an indescribably forbidding face of a peak, e.g., the Trisul may rise thousands of feet above the surrounding ground. In places occur the overhanging rocks with snow-fluted precipices dropping several thousands of feet. The Naga Parbat rises from the Indus Valley more than 20,000 feet below. The slopes are not only very precipitous in places with crevasses and chasms, but ice walls, ice falls, rock walls, etc. are common. In places enormous and treacherous scree slopes also occur.

As noted already precipitation is mainly in the form of snow and the lower regions represent a land of glaciers with all their characteristic features showing crevasses, a series of surface moraines, etc. In places there is so much moraine matter or an incredible quantity of rock may cover the ice that it appears

like a glacier of rocks. Some of these glaciers are gigantic in size, both longitudinal and transverse in trend. Sometimes a glacier valley is narrow and there one feels deep down as in a crevasse between walls rising 10,000-12,000 feet above the valley bottom, only two miles in width. There is no doubt that since the Pleistocene Ice age they have definitely retreated as glacial lakes representing rock basins originally scooped out by glaciers exist at levels lower than where they descend today. From their snouts issue forth streams which may follow a longitudinal trend for some distance, but then pierce the Great Himalaya and carve out deep and narrow gorges. In more resistant rocks like the granite these gorges become especially constricted and sides of 1,000 feet in elevation or more above the bed of the river are quite common. The bed may be further choked with blocks fallen from above and the foaming water of the rushing torrent has to struggle through them to proceed downstream. Thus in this region the action of frost, and the work of snow and ice are seen at their best in the sculpture of its mighty peaks, knife-edged ridges, awe-inspiring and forbidding faces, glaciated valleys, moraine deposits, etc. Finally the work of normal erosion in carving out deeping valleys and gorges has been referred to above.

## Distant Views of the Great Himalaya

Before I conclude I would like to refer to the distant views observed of the Great Himalaya on my trek between Tehri and Gangotri. These views give a comprehensive and broad glimpse of this part of the range.

The first beautiful view of the snow-clad Great Himalaya was observed at Chamakhal, 13 miles before Tehri. The range was observed to run practically east-west with a lower range running parallel to it. The other lower ranges had obviously been dissected by the valleys.

Again a glimpse of the snows was observed a little above Margaon, through a pass in the lower range. A little farther

on a part of the snow-clad range was observed showing a pyramidal peak with almost vertical southern face.

From the confluence of the Sian Gad with the Bhagirathi looking eastwards a practically snow-clad peak of the Himalaya was seen. It may be noted that although it was almost dark in the valley in the evening, the peaks were observed to be sunlit. As observed before Vagori near Harsil, dark peaks with a silvery-white snow against the red glow of the evening sky made a very lovely sight indeed.

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*From the Journal of the Asiatic Society. Science.*
*Vol. XXI, No. 1, 1955.*

# THE EXTERNAL RELATIONSHIPS OF THE INDIAN FRESH-WATER FISHES, WITH SPECIAL REFERENCE TO THE COUNTRIES BORDERING ON THE INDIAN OCEAN.*

*By* A. G. K. Menon, *M.A., M.Sc., Assistant Zoologist, Zoological Survey of India, Calcutta.*

(Communicated by Sunder Lal Hora, F.A.S.)

(*Paper received on 6th November, 1954.*)

## Introduction

In a recent communication (Menon, 1953) dealing with 'the age of the transgression of the Bay of Bengal and its significance in the evolution of the fresh-water fish fauna of India', it has been shown that there are 89 genera of primary fresh-water fishes in the Indian waters. In this paper their external relationships to the countries bordering on the Indian Ocean are traced and their geological ages and the factors that influenced their migration are discussed. Günther (1880), Day (1885), Blanford (1901) and Hora (1944) have already referred to the geographical relationships of the Indian fresh-water fishes. Günther (*loc. cit.*, p. 225), relying on groups instead of genera and species, concluded that 'there exists a great affinity between the Indian and African regions; seventeen out of the twenty-six families or groups found in the former are represented by one or more species in Africa, and many of the African species are not even generically different from the Indian'. Day (*loc. cit.*, p. 317), after a careful study of the Indian fresh-water fishes, came to an entirely different conclusion. According to him 'in India, as restricted, I found 87 genera of fresh-water fishes, of which only 14 have representatives in Africa, while among the 369 species of which these genera are composed, only 4 extend to Africa. If we examine the relationships of the same fauna to this restricted Indian area we find, of the 87 genera, 44 extend to the Malaya Archipelago, and of the 369 species, 292 are present in both localities'. After Day, Blanford (*op. cit.*) referred to the distribution of fresh-water fishes and his conclusions supported those of Day. Further, from his study of the other groups of vertebrates, he concluded (p. 433-34):

> 'The Indo-Malayan element in the fauna is very richly represented in the Eastern Himalayas, and gradually diminishes to the westward, until in Kashmir and further west it ceases to be the principal constituent. Almost all the Indo-Malayan genera, and a large portion of the species, are identical with Assamese and Burmese forms. These facts are consistent with the theory that the Indo-Malayan part of the Himalayan fauna, or the greater portion of it, has migrated into the mountains from the eastward at a comparatively recent period. It is an important fact that this migration appears to have been from Assam not from the Peninsula of India.'

* Published with the kind permission of the Director, Zoological Survey of India, Calcutta. This paper was read at the Second Congress of the Pan Indian Ocean Science Association held in August 1954, at Perth, Australia.

Hora's extensive studies of the Indian fresh-water fishes also support the views expressed by Day and Blanford. Hora (1937, p. 351) stated:

> 'I have been greatly struck by the close similarity of the Indian forms to those found towards the east in Indo-China, Siam, and the Malay Archipelago. As a result of a detailed study of the genera and species inhabiting these regions, I am definitely of the opinion that the fresh-water fish fauna of India in the main originated in south-eastern Asia, most probably in Indo-China, and spread westwards by successive waves of migration to India and later to Africa while the two masses of land were connected with each other.'

Since then much advance has been made by Hora and his pupils in the fish geography of India and it has now been possible to explain most of the anomalies in the present-day distribution of the fresh-water fish fauna of India, especially the presence of the Malayan element in the fauna of Peninsular India in terms of a main route of migration along the Satpura trend of mountains (Hora, 1949). I shall in this paper, however, discuss the distribution of the Indian fresh-water fishes only in such detail as would clearly bring out their relationships to the countries bordering on the Indian Ocean.

## Extinct fresh-water fish fauna of India and its external relationships

The earliest known fresh-water fishes from India are referable to the genus *Ceratodus* Ag. from the Maleri beds in the Godavari valley of the Upper Triassic period, approximately 170 million years old (Hora and Menon, 1952). This genus, from its fossil records (Hora and Menon, *op. cit.*), seems to have evolved in the Northern Hemisphere during the early Triassic period and spread to the Southern Hemisphere probably along the corridor that stretched across the Tethys sea connecting Peninsular India with the North through the present-day Assam probably up to the Middle Eocene (Menon and Prashad, 1952). From India, the genus seems to have spread over the whole of the Gondwana Continent, which, besides Peninsular India, included Madagascar, the southern parts of Africa, South America and Australia. No Lung-fish is found today in India, though forms allied to *Ceratodus* are living today in Queensland, Australia (*Epiceratodus* Teller), South Africa (*Protopterus* Owen), and South America (*Lepidosiren* Nutt.). The Ganoids, which originated in Europe during the Middle Devonian times, were the second group of fishes that entered India during the Upper Jurassic, probably along the same route as the Dipnoans (Hora and Menon, *op. cit.*). The Ganoids of the extinct genera *Lepidotus*, *Tetragonolepis* and *Dapedius* colonized Indian waters and dispersed over the whole of the Gondwanaland in the same way as the Dipnoans. From India they were, however, entirely wiped out, probably due to the desiccation that followed the Jurassic epoch, though their near relations are still living in other parts of the world. Their fossils are known from the Kota beds of the Godavari Valley, approximately 145 to 120 million years old. During the Cretaceous there seems to have occurred another wave of Ganoid migration into India consisting of the genera *Pycnodus* and *Lepidosteus*. Their fossils are known from the Lameta beds at Dongargaon, Madhya Pradesh. During the early Eocene another wave of migration from the north to India consisting of *Lepidosteus* and certain Teleostean fishes of the families Osteoglossidae, Cyprinidae, Anabantidae and Nandidae had occurred, but since the Gondwanaland had by then started cracking between India and Australia, cutting off the land

route between these two countries, these fishes had not spread to Australia, but only to Africa and South America. In India fossils of these fishes are known from Deothan, Kheri, Takli and Paharsingha in Madhya Pradesh. This fauna, however, became entombed in the successive lava eruptions of the early Eocene epoch and there are no more fossil records of fresh-water fishes from Peninsular India after the Lower Eocene. Pliocene fossils of *Clarias* Scopoli, *Heterobranchus* Geoffroy, *Channa* Scopoli, *Chrysichthys* Bleeker, *Mystus* Scopoli, *Rita* Bleeker, *Bagarius* Bleeker and *Silurus* Linnaeus are, however, known from the Siwalik deposits of the Himalayas (Hora and Menon, 1953).

## RECENT FRESH-WATER FISH FAUNA OF INDIA AND ITS EXTERNAL RELATIONSHIPS

As pointed out above there are 89 genera of primary fresh-water fishes which can be divided into the following 4 groups according to their external relationships to the countries bordering the Indian Ocean.

### *Group I.*

The genera listed below are common to India [1] and to one or more of the countries bordering on the east [2] as well as on the west [3].

1. † *Notopterus* Lacépède
2. * *Barilius* Hamilton
3. * *Rasbora* Bleeker
4. * *Cirrhinus* Oken
5. * *Garra* Hamilton
6. * *Labeo* Cuvier
7. * *Puntius* Hamilton
8. * *Tor* Gray
9. †† *Oreinus* McClelland
10. †† *Schizothorax* Heckel
11. * *Nemachilus* Van Hasselt
12. ** *Mystus* Scopoli
13. †† *Silurus* Linnaeus
14. †† *Glyptothorax* Blyth
15. * *Channa* Scopoli
16. * *Clarias* Scopoli
17. * *Anabas* Cuvier
18. * *Ambassis* Cuvier and Valenciennes
19. * *Mastacembelus* Scopoli

### *Group II*

Group II consists of a single genus which is common to India (West Punjab) and the countries on the west (Baluchistan and Persia).

*Scaphiodon* Heckel

### *Group III*

The following genera are common to India and to one or more of the countries on the east.

1. *Chela* Hamilton
2. *Laubuca* Bleeker
3. *Esomus* Swainson
4. *Danio* Hamilton

[1] Under India, Pakistan and Ceylon are included, though politically, and in the case of Ceylon even geographically, they form separate countries. It may be pointed out here that Ceylon was intermittently connected with the mainland as late as or even later than 10,000 years ago (Jacob, 1949).

[2] The countries bordering the Indian Ocean on the east are Burma, Malaya, Sumatra and Java.

[3] The countries bordering the Indian Ocean on the west are Baluchistan, Persia, Arabia and Africa including Madagascar.

* Found both in Africa and Ceylon; † not found in Ceylon; ** not found in Africa; †† found neither in Africa nor in Ceylon, towards the west they occur as far as Afghanistan or Baluchistan, Persia or Syria.

5. *Acrossocheilus* Oshima
6. *Amblypharyngodon* Bleeker
7. *Aspidoparia* Heckel
8. *Crossocheilus* Van Hasselt
9. *Catla* Cuvier
10. *Oreichthys* Smith
11. *Osteobrama* Heckel
12. *Osteochilus* Günther
13. *Rohtee* Sykes
14. *Schismatorhynchus* Bleeker
15. *Thynnichthys* Bleeker
16. *Psilorhynchus* McClell
17. *Homaloptera* Van Hasselt
18. *Acanthophthalmus* Van Hasselt
19. *Botia* Gray
20. *Lepidocephalichthys* Bleeker
21. *Semiplotus* Bleeker
22. *Ompok* Lacépède
23. *Wallago* Bleeker
24. *Batasio* Blyth
25. *Rita* Bleeker
26. *Amblyceps* Blyth
27. *Bagarius* Bleeker
28. *Euchiloglanis* Regan
29. *Exostoma* Blyth
30. *Gagata* Bleeker
31. *Laguvia* Hora
32. *Pseudecheneis* Blyth
33. *Chaca* Cuvier and Valenciennes
34. *Clupisoma* Swainson
35. *Eutropiichthys* Bleeker
36. *Pangasius* Cuvier and Valenciennes
37. *Pseudeutropius* Bleeker
38. *Heteropneustes* Muller
39. *Fluta* Bloch and Schneider
40. *Olyra* McClelland
41. *Colisa* Cuvier and Valenciennes
42. *Badis* Bleeker
43. *Nandus* Cuvier and Valenciennes
44. *Pristolepsis* Jerdon
45. *Macropodus* Lacépède
46. *Rhynchobdella* Bloch and Schneider

*Group IV*

The following genera are endemic to India:

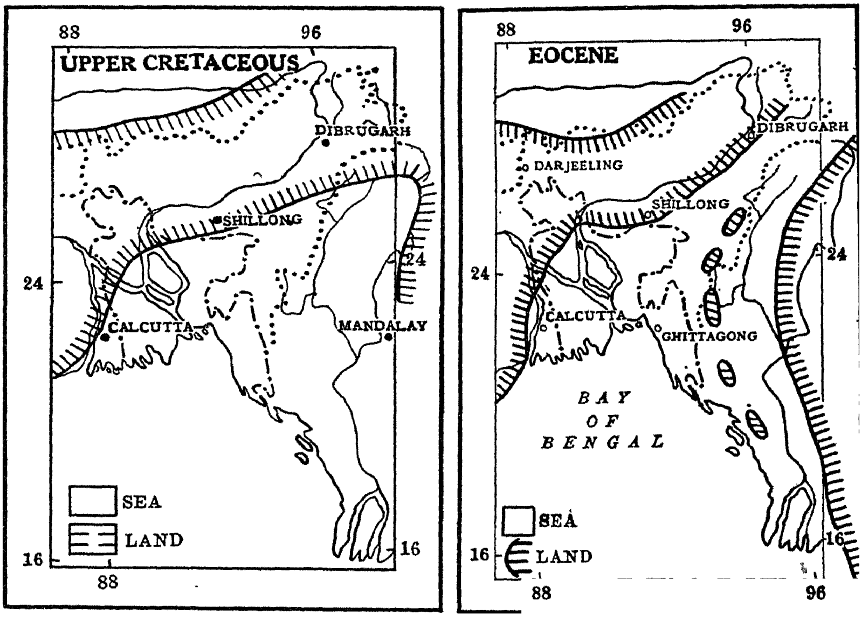
1. *Parapsilorhynchus* Hora
2. *Lepidophygopsis* Raj
3. *Balitora* Gray
4. *Bhavania* Hora
5. *Travancoria* Hora
6. *Aborichthys* Chaudhuri
7. *Jerdonia* Day
8. *Nemachilichthys* Day
9. *Somileptes* Swainson
10. *Horabagrus* Jayaram
11. *Conta* Hora
12. *Erethistes* Muller and Troschel
13. *Erethistoides* Hora
14. *Hara* Blyth
15. *Myersglanis* Hora and Silas
16. *Sisor* Hamilton
17. *Ctenops* McClell
18. *Ailia* Gray
19. *Neotropius* Kulkarni
20. *Proeutropiichthys* Hora
21. *Silonia* Swainson
22. *Horaglanis* Menon
23. *Amphipnous* Muller

From the above analysis, it may be seen that of the 89 genera occurring in India, excepting 23 endemic genera, 66 have relations with neighbouring countries bordering the Indian Ocean. Of these 66 genera, 19 are common to countries in the east as well as those in the west. This accounts for 29% of the 66 genera. The genus common to India and the countries on the west accounts for another 2%. There are 46 genera common to India and to the countries in the east, i.e. about 69%. Further, it is remarkable to note that there is not a single genus common to India and Africa, which is also not found in the countries of the east. It is abundantly clear from these data that the relationships of the fresh-water fish fauna of India are with that of the Malayan fauna (Hora, *op. cit.*) and that there is hardly any typical Ethiopian element in it. A close examination of the endemic genera also shows that they are closely related to forms found in the countries towards the east of India (Hora, 1937*a*; 1944, pp. 426–28; Silas, 1952).

ORIGIN AND SPREAD OF THE PRESENT-DAY FRESH-WATER FISH FAUNA OF INDIA

I have referred earlier to the corridor that stretched across the Tethys Sea connecting Peninsular India with the north through the present-day Assam and along which the Dipnoans, the Ganoids and certain Teleosts had spread to the Peninsula. This fauna having been completely annihilated by the Eocene epoch (*supra*, p. 3), the chances for its further invasion had also been cut off owing to the transgression of the Bay of Bengal during the Middle Eocene and the submergence of the Assam land connection between the Peninsula and the north (Menon and Prashad, *op. cit.*).

Thus during the Upper Eocene, Miocene and early Pliocene periods, when the Bay of Bengal extended northwards to China and Tibet separating India from the rest of Asia, the monsoon bearing winds had crossed to the north over this gulf making the climate of the Yunnan region, which was then a low land, temperate and equable (Hora, 1953). These conditions




TEXT-FIG. 1. (*a*) Distribution of land and sea in the Bengal, Assam and Burma regions during the Pre-Bay of Bengal transgression India in the Upper Cretaceous and the same during the Post-Bay of Bengal transgression India in the Middle Eocene which cut off the land connections between India and the Far East. (After M. S. Krishnan, *Bull. Nat. Inst. Sci. India*, **1**, pp. 25–29, 1952.)

had probably facilitated the evolution of a rich and specialized fish fauna there but it did not spread to India until the Pliocene when, with the major upheaval of the Himalayas, the land connection between India and farther east was once again established. Fossils of *Clarias*, *Heterobranchus*, *Channa*, *Rita*, *Bagarius* and *Silurus* indicate that during the Pliocene the migration of fish was entirely along the Himalayas. The Garo-Rajmahal gap was still under the sea and did not permit the Pliocene fish fauna to migrate southwards (Menon, *op. cit.*).

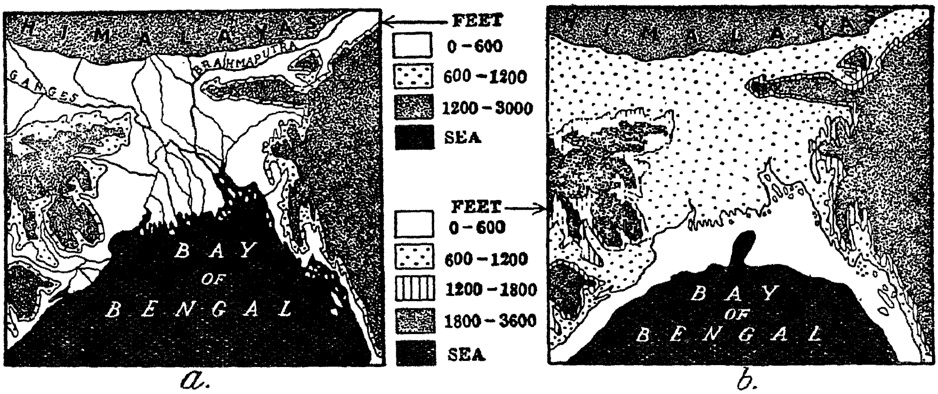
During the Pliocene the South Chinese fish fauna had, however, spread not only along the Himalayas, but also further westwards to Africa *via*

Afghanistan, Persia, Syria and Arabia. It has already been shown (Menon, 1951) that during the Pliocene, wet, tropical conditions prevailed along the whole of the southern face of the Himalayas extending to China in the east and beyond Baluchistan towards the west, thus facilitating the spread of the marsh-loving fishes from south-west China to as far west as Africa. Most of the fishes of clear flowing water are, however, Pleistocene migrants. The typical Himalayan fauna consisting of *Nemachilus*, *Garra*, *Tor*, etc. which is not only characteristic of the hill-streams of the Oriental region, but also those of Persia, Arabia, Syria and Africa, had undoubtedly originated somewhere in south China and dispersed along the Alpine Himalayan system and its southern loops in Europe and Western Asia and the other associated mountains (Hora, 1951) during the Pliocene and early Pleistocene[1]. During the end of Pliocene or early Pleistocene a second major upheaval of the Himalayas had occurred which raised the Siwalik sediments into dry land and the Siwalik fore-deep (Krishnan, 1934) gradually disappeared leaving a shallow depression—the Pleistocene fore-deep, which with the formation of the Assam Plateau by then, began draining northern India from Assam to the Arabian Sea (Hora, 1953*a*). This Pleistocene river was probably not pouring into the sea exactly at the place where the Indus today joins the Arabian Sea for 'the floor of the north-western part of the Indian Ocean as we know it today assumed its present form as a result of compression in Tertiary times, probably contemporaneously with the upheaval of the Alpine-Himalayan Mountain system and the Arcs of the Malay Archipelago and the formation of the Rift Valley. Consequently, in Pliocene or Post-Pliocene times the area of land that once filled the triangle now bounded by the northern part of the East African Coast and its continuation, the south-east coast of Arabia, the Baluchistan coast and the west coast of India, became separated off by a series of faults and was submerged to its present depth' (Wiseman and Sewell, 1937).

From the present-day distribution of fresh-water fishes it would appear that the land-mass between the East African coast and the south-east coast of Arabia, the Baluchistan coast and the west coast of India had submerged only quite recently, probably simultaneously with the birth of the Ganga and the Indus. Till then the present-day Persian Gulf must have probably been a river valley in continuation of the Euphrates-Tigris basin and the Pleistocene fore-deep of the Himalayas may have had connections with it during the Pluvial periods of the Glacial epochs. Thus, from the Asian plateau in the east up to the headwaters of the Euphrates and the Tigris rivers there must have been a continuous route along which the fishes may have got widely dispersed.

[1] Though *Garra*, *Tor* and *Nemachilus* have many representatives in Africa, including certain primitive forms, it should not, however, be considered as an evidence of the origin of these genera in Africa and their transference from there to the east. In the case of the family Clariidae, I have already pointed out (Menon, *op. cit.*) how the family under favourable conditions in Africa had thrown out innumerable genera and species there and how the primitive genus *Heterobranchus* had continued to exist unchanged in Africa on the one hand and the Malay Archipelago on the other, while it has entirely disappeared from countries between them except as fossils in the Siwalik deposits in India. Primitive genera and species would, therefore, continue unchanged if environmental conditions of their habitats remain unchanged. The evolutionary history and the distribution of the Marsupials (de Beaufort, 1951, p. 148) and the Dipnoan fishes (Hora and Menon, *op. cit.*) are further examples illustrating this point. Both Marsupials and the Dipnoans were once distributed all over the northern continents, but were driven southwards into their present 'blind alleys' in the southern isolated continents where these primitive forms are still thriving while they have become entirely exterminated in their respective places of origin.

I have pointed out earlier that the Garo-Rajmahal gap was under the sea during the whole of the Pliocene period and had therefore practically no migration of the fish fauna from the north to the Peninsula was possible. Only during the Pleistocene the Garo-Rajmahal gap became a dry land facilitating the migration of fishes to the south. During the Glacial periods




TEXT-FIG. 2. The Physiography of the Garo-Rajmahal Gap. (*a*) Present-day conditions, (*b*) During the height of a glacial period. (After S. L. Hora, *Proc. Nat. Inst. Sci. India,* 17, p. 439, 1951.)

of this epoch, aeustatic drop in the sea level of 600 feet had actually bridged up the Garo-Rajmahal gap topographically and climatically enabling the fresh-water fishes, especially the hill-stream forms, to cross over from the north to the Peninsula (Hora, 1951*a*). There was also greater run-off of water in the streams and rivers especially in the big river like the Narbada-Tapti along the Satpura-Vindhyas during the Ice-ages of the Pleistocene enabling the quick spread of the fish fauna from the north to the Peninsula.

To sum up it may be emphasized that the evidence of the distribution of the fresh-water fishes of India clearly indicates their South Chinese origin and their subsequent spread to the west along the Himalayas on the one hand and to the south-east along the Burma-Malaya arc and the Indo-Malayan mountains. There is thus no African element in the fresh-water fish fauna of India. On the other hand, it is the Indian element that is present in the fauna of Africa at the present time.

## ACKNOWLEDGEMENTS

My grateful thanks are due to Dr. S. L. Hora, Director, Zoological Survey of India, and to Dr. E. Trewavas of the British Museum for kindly going through the manuscript and giving me many helpful suggestions.

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